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A Report of the Research Council

By F. M. DAWSON

Vice President of the A.S.E.E. and President of the Engineering College Research Council

The members of the Society have special reason to be interested in the activities of the Society's Administrative and Research Councils. The Engineering College Research Council has continued a number of important activities since its report at the Annual Meeting in Minneapolis last summer. A few of these activities are reviewed herein.

Copies of the Research Council's 1947 Directory, including a complete Review of Current Research at our member institutions, were distributed in Minneapolis. Since then complimentary copies of this publication have been sent to nearly 1,500 industrial research laboratories in the United States, and several hundred additional copies have been sold at the regular price of $1.00.

Papers presented at the Research Council's sessions in Minneapolis were assembled and published in the *Proceedings* of the 1947 Annual Meeting. The libraries of all our member institutions and members of the Industrial Research Institute have received complimentary copies of the *Proceedings,* and we have supplied a number at $1.00 each.

The program of our Committee on Relations with Federal Research Agencies remains active; at the request of the U.S. Army Corps of Engineers, we have recently asked our members to indicate their possible interest in a study of electric blasting problems. The Committee is apparently able to give a substantial service to government agencies by canvassing our members' facilities and interests.

In this connection, the Research Council held a midseason meeting in Washington on November 12, at which five representatives of key government agencies spoke about their present and future plans for sponsoring research at engineering colleges. Guests of the Research Council at the meeting were Rear Admiral Paul F. Lee, Chief of the Office of Naval Research; Major General L. C. Craigie, Director of Research and Development, Department of the Air Force; Major General H. S. Aurand, Director of Research and Development, Department of the Army; Dr. L. R. Hafstad, Executive Secretary of the Research and Development Board, National Military Establishment; and Dr. Ralph P. Johnson, Deputy Director, Research Division, U. S. Atomic Energy Commission. A lively discussion period followed each paper.

Historically, the Engineering College Research Association (predecessor organization to the Research Council) was one of the first engineering organizations to take an active part in the fight for the National Science Foundation. As a result of this (and others') frontier work, the principles involved in a National Science Foundation have

gained fairly wide acceptance, and the field of engineering is now almost certain to be specifically included in any National Science Foundation bill. The defeat of the Foundation during the last two years has resulted from disputes over administrative details rather than from a refusal of any of its principles.

As the 1948 session of Congress draws near, the Society is making plans to continue its non-partisan support of the National Science Foundation, expressing willingness to accept any sound administrative pattern so long as the Foundation's purposes are achieved. This is in accordance with the resolution passed at the Annual Meeting in Minneapolis last June, when the Society's Committee on Legislation was authorized to "take all necessary steps to secure passage of a National Science Foundation bill provided that it is in general consonance with S. 526." The Research Council expects to maintain its active interest in the Science Foundation, in accordance with this resolution, and there is hope that a National Science Foundation can be created during 1948.

Agricultural Engineering—Its Place in the Land-Grant Schools*

By ARTHUR W. TURNER†

It is always a pleasure to discuss the importance of Agricultural Engineering in our domestic life and in the world economic picture. The opportunity of presenting it to you is a special privilege which I greatly appreciate. By way of introduction and background, I am an agricultural engineer by graduation, taught on an agricultural engineering staff, served nearly a score of years in industry as an agricultural engineer, and now am directing agricultural engineering research in the U. S. Department of Agriculture.

Engineers like to identify themselves according to the industry they serve. So, there are transportation, marine, automotive, electrical, mining, petroleum, and other kinds of engineers serving industry in its many phases. The agricultural engineers' industry is agriculture.

Agriculture is America's largest industry. It is a large user of power, labor, and materials. Prior to the war, American manufacturing and processing industry had 50 million horsepower available, while agriculture had 97 million. The 1940 census reported that 18.45 per cent of all persons gainfully employed were in agriculture as compared with 24.3 in all manufacturing. American agriculture purchases more than one-third of a billion dollars worth of building materials annually, more than three-fourths billion dollars worth of machinery and equipment, and over half a billion dollars worth of fertilizer, which is rapidly becoming a major commodity of the chemical industry. Agriculture is the petroleum industry's largest customer, while the immediate and potential consumption of electricity by agriculture is enormous. Now transmission lines provide power for more than three and one-half million separate farms, each with unlimited applications of electric energy. Agriculture is big business, America's largest. Agriculture was the world's original industry and still is its basic industry, and as such deserves a goodly number of specially trained engineers.

World Food Needs.

The importance of food in war and in peace is recognized throughout the world. In the world economic and political situation recently much emphasis has been placed on food—food for a starving world. An outstanding engineer, Herbert Hoover, former President of the United States, and Chairman of the President's recent Famine Relief Committee, made this

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* Presented at the Engineering Education Section, Association of Land Grant Colleges and Universities, Washington, D. C., November 10, 1947.

† Assistant Chief, Charge of Agricultural Engineering Research, Bureau of Plant Industry, Soils and Agricultural Engineering, USDA.

statement on his return from a world inspection tour:

"Calories are the yardstick of hunger, of starvation, of famine, and finally death. . . . As we descend the scale from the stage of hunger, to the stage of disease and epidemics, to the stage of public disorder, to the stage of starvation of all but the strongest, we come finally to the stage of mass starvation at less than 900 calories a day. . . . Long before a population is reduced to these low levels, however, Government would break down. We must prevent the descent to these lower levels. Reconstruction and peace in the world would go up in the flames of chaos if we were to fail."

The importance of food as a stabilizing influence in the world was recognized by the formation of the Food and Agriculture Organization and ratification of its constitution by 42 nations at Quebec, Ontario, October 16, 1945, as a vital part of the UNO. Apropos of the importance of food in world peace, Sir John Orr, Director General of FAO, made this statement at the first plenary session of the organization at Washington, D. C., devoted to urgent food problems.

"The cooperation of government in a common effort to free the world from hunger will do more for an enduring peace than the delineation of political boundaries and the drawing up of political peace treaties, essential though these may be. Famine is the greatest politician of all. Peace cannot be built on *a foundation* of empty stomachs."

I was asked to prepare a paper for the International Technical Congress held in Paris, France, in September of last year on the subject "The Impact of Mechanization on Agriculture." I raised the questions: "Will this demand for more food be met by further mechanization? Can other nations increase their production in this same way?" I answered these questions by saying, "Not by mechanization alone. Mechanization, as we know it in the United States, is more than just replacing hand methods by machines in crop production. It is agricultural engineering—applying engineering principles to agriculture in soil conservation, in farm buildings including both animal shelters and grain storages, and the efficient use of electric energy as well as mechanical power and farm machinery—all of which are dependent through management and are part of what, for lack of a better term, has been called 'farm mechanization.'"

I am now a member of a committee attempting to set up a procedure under the "Marshall Plan" to provide the 16 European countries with needed food production tools—farm machinery. This has to be determined very realistically for we in this country have increased our food demands by 10 per cent since the start of the war. Our population is 13,000,000 greater. And you people, burdened with present university enrollment, no doubt agree with the October 15 United States News charts showing that our population will be 150,000,000 by 1950. Every person is a mouth to feed and a body to clothe.

Can we increase our production to meet these additional demands? Some of you civil engineers will no doubt point to the vast areas that can be brought under cultivation through irrigation. Possibly this can be done to give us some increased production. But what are we going to do about the thousands of acres of fertile land that are being flooded to provide hydroelectric power and ruthlessly stripped for coal and other natural resources, the large areas being destroyed in oil fields, good soil used for fill in major

construction, and the burying of good soil in covering dumps and similar areas. Will not this waste of our basic resource offset to a large degree what we gain through reclamation unless our conservation programs are made more effective?

The alternative to increased production from more land is to boost our food and fiber production from the present cultivated area through advancements in science and engineering. Hybrid corn is, of course, the best example of how this can be done. That one advancement, which was made possible only through research, gave us 2 billion additional bushels of corn during the war years. Such production would not have been possible, however, had it not been for other developments, particularly in agricultural engineering, which made possible the mechanization of many production operations, including precision planting and mechanical harvesting. The change from horsepower to machine power alone released many thousands of acres which became available for increased production of foods. It also increased our efficiency in many other ways. These changes were the result of research, both public and private, in the field of agricultural engineering. In this post-war period agriculture's research men are not looking backward; they are, instead, looking ahead at new problems that challenge the imagination.

Some Agricultural Engineering Problems

Let me list a few of the questions now under consideration in agricultural engineering research:

1. What new equipment and changes in methods are needed in harvesting and curing hay? Dairy nutrition specialists say enough protein is now lost in handling hay to feed 7,500,000 dairy cows for six months. That indicates rather emphatically that methods now used in harvesting this valuable crop are awkward, inefficient, and antiquated. The development of new haying machines and procedures is largely an engineering problem.

2. What crop conditioning requirements and facilities does the producer need so he can hold and market his commodities in top quality condition at his own convenience rather than to dump them on a flooded market at harvest time? This question opens up a whole field of engineering research that is relatively unexplored.

3. What are the economic factors involved in the production and decortication of new fiber crops, such as ramie, sansevieria, and others, on an industry basis? The present world shortage of fibers which is especially serious in this country indicates the pressing need to accelerate research that may lead to new fiber industries and establishment of our own fiber industries.

4. Can tobacco, cotton, peanuts, sweet potatoes, and similar crops be mechanized for quantity production and quality control? On many of these products the surface of the research that needs to be done has barely been scratched.

5. How valuable is the labor that is performed about the farm buildings in caring for livestock and crops? In dairying, for example, and in producing poultry and eggs, up to 80 per cent of the labor time is spent in the buildings. The time required to care for one cow ranges from 100 to 165 hours a year with an average of 140 hours, while a flock of 125 laying hens and pullets will require approximately 200 hours. Compared with crop production these requirements are extremely

high. What is needed in new machinery or equipment and arrangement of buildings and work procedures to reduce the labor needed?

6. How much does the producer pay for inefficiency in farm processing plants and small industries handling farm products, and what can engineering do to reduce costs? Output per worker varies as much as 25 per cent in creameries within boundaries of a county, 800 per cent in milk marketing, and 65 per cent in poultry processing plants.

7. What do we need to know about housing farm animals to lower costs of production, improve quality of product, and maintain the health of the animals? Engineers need scientific data on the heat and moisture production of the various kinds of animals in order to provide the right environment for high production and to protect the structures themselves from damage by decay and other ravages.

8. Can the potentiometer be used to supplant the seed germination test as a means for determining seed viability and growth characteristics? Some experiments have shown rather startling results and indicate this instrument may have untold value to the plant breeder.

9. Does anyone know or can any of us even imagine the potentials from use of bactericidal, erythemal, and infrared energy in agriculture? In this field of electric radiation preliminary explorations have already indicated a tremendous field for research of especial immediate interest on the possibilities of supersonic energy and its effects on plant, bacterial, insect, and animal life?

10. What types of refrigeration equipment for farm use will be required in the future? Insofar as farm applications are concerned, refrigeration is just in its infancy. The possibilities of freezing fresh milk on the farm are, for example, just becoming known. In the not-too-distant future, also, poultry may be fresh-dressed, frozen, and sold directly from farms. With further research in farm refrigeration, the marketing of many perishable farm products might easily be revolutionized. Equipment to handle such demands has not yet been designed.

Many Engineering Research Phases

Those are only a few of the problems of the moment about which agricultural engineers are thinking. In agricultural research it is sometimes difficult for many to distinguish the engineering phases because so often the work is set up by commodities—cotton, corn, hogs, cattle, or other crops or animals. In all these fields, however, there are engineering phases. This work might well be described as functional research because so often it deals with the functions of production, storage and housing, processing, and marketing. In Agricultural Engineering the investigations are concerned not only with crops and their production but also with the functional requirements of livestock shelters, the development of more livable homes, and the efficient use of labor and both mechanical power and electricity on the farm and in the rural farm industries. You will be interested to know that estimates have been made showing that 85 per cent of the nation's vast agricultural research program has engineering phases or implications.

Training of Agricultural Engineers

Recognizing that there is a need for increasing food production throughout

the world, there must be a need also for more agricultural engineers, for they are in reality the engineers of food production. What background must such an engineer have? Here is a brief resume of some of the requirements:

He must, of course, be an engineer because he deals with power, labor, methods, and materials. He must also know farming and the problems of crops and livestock production, processing, and marketing. In other words, he must know agricultural fundamentals in addition to having the technical knowledge of the engineer who goes into any other industrial field.

The agricultural engineer needs a knowledge of soil tilth with regard to respective kinds of soils, climate, and crops. One might refer to this as soil physics. What is the nature and frequency of cultivation needed to control weeds and to stimulate maximum production in any given soil and for each particular crop? What are the possibilities of using chemicals, heat, and electric energy in weed treatment in the various field operations? These require a background of agricultural training for their solution.

The agricultural engineer also needs a working knowledge of plant science and a close relationship with the plant breeders. He knows the characteristics he desires in seeds or seedpieces for precision planting, and such characteristics as the type of straw or stalks desirable for harvesting. For harvesting, the ideal situation would be to have a universal machine for all crops. However, this seems impossible because of the wide variety of the present physical characteristics of the crops. Probably, however, individual machines can be adapted to harvesting a wider variety of crops than is now done.

Thousands of varieties of insects attack our crops and animals. The entomologists develop insecticides and fungicides, both liquid and dust, but they and equipment manufacturers have been stymied by lack of satisfactory methods and equipment for application, whether by ground or airplane means.

Training by Land-Grant Colleges

How and where should the agricultural engineer be trained? Here I am giving my personal views, based on observation of engineers in all branches of agriculture. The logical place for training is the land-grant college having both engineering and agricultural staffs. Possibly there are exceptions; however, I am sure you will agree with my first statement. The agricultural engineer needs a strong agricultural engineering consciousness that will enable him to understand and apply engineering principles to agriculture in a scientific as well as practical manner. Every state can and, I believe, should have at least one strong agricultural engineering department.

Personally, I do not fully subscribe to four years of engineering training and one year of agriculture, or four years of agriculture and one or more years of engineering. Neither procedure developes a proper agricultural engineer consciousness. Institutions having a 4-year curriculum in engineering should have a 4-year curriculum in agricultural engineering.

The administration of agricultural engineering training—and here is where I again open myself to questions from some of you—to my thinking should be a joint responsibility between the Dean of Engineering and the Dean of Agriculture. The engineering requirements of agriculture are a combination of engineering fundamentals and agricultural

fundamentals. They are not the so-called trades or skills but the basic fundamental requirements of the two professions: one without the other is apt to result in lopsided training and subsequently lopsided viewpoints.

It will not be sufficient in developing the agricultural engineering curriculum to reshuffle the present engineering and agricultural courses and expect the agricultural engineering student to sift out the wheat from the chaff. One of the handicaps in agricultural engineering training today is insufficient text materials and teaching examples of engineering applications to agriculture. It is essential to study not only the overall curriculum, but also to organize some special agricultural engineering courses. This applies to both engineering and agriculture. Take the applied mechanics of field machines for example. Agricultural equipment does not have the solid foundation of the power-generating plant, the steel rails of trains, or the concrete roads necessary for operation of motor vehicles. Instead farm machines operate over uneven terrain. Power is transmited at angles by sprocket, shaft, belt, and chain, and through the power-take-off, and the angles change in both horizontal and vertical planes while the machine is in operation, either to meet terrain irregularities or crop requirements.

Another example includes farm buildings which represent a large part of the farmer's investment and affect his income in several ways. Where climatic conditions are unfavorable the amount of milk or eggs that a farm produces is likely to depend on the capacity or the convenience of the buildings. Storing the various crops is dependent on the conditioning requirements of each crop; how much moisture is transferred from the center of a kernel or seed to the surface where it can be evaporated or removed. Controlling or eliminating moisture migration in grain storages is another essential in grain storage design.

Specialized courses in engineering and especially in agriculture could concentrate much essential material into fewer and more useful courses. For example, take the material on soil physics already mentioned. One good course on soil physics could cover soils if presented as related to the structure of soils, characteristics which affect tillage, traction, erosion, and similar factors. Livestock should be studied from the standpoint of housing and care instead of merely judging individual animals. Field crops should be studied from the mechanical standpoint for production and agronomic standpoint for storage and utilization.

Another course which I believe should be in every engineering curriculum has to do with the engineer's responsibility for developing and understanding the economic and social phases of his work. One of the greatest dangers to our constitutional form of government and our free economy is the lack of appreciation of how these two great institutions serve everyone and have provided us with the highest standard of living ever achieved. Again and again in meetings and papers of our engineering societies it has been emphasized that the people responsible for high standards must also assume responsibility for translating and publicizing just how our system operates. Our responsibility as engineers is to correct misunderstandings about our economic system, and thus to stop the dangerous undermining which has been going on in some quarters.

The training of the agricultural engi-

neer has the same relationship to agriculture as that of the mining engineer to mining and the aeronautical engineer to aeronautics. It is an engineering profession serving the agricultural industry. That industry, in many of its phases, calls for the highest type of engineering, a far advancement from its beginning as farm mechanics. Its true importance stands out in bold relief.

And now in conclusion permit me to ask your counsel on how our training and applications of engineering can be strengthened. Increasing numbers of young men feel a responsibility in applying engineering to agriculture. Many agricultural engineers are already doing yeoman service. Both deserve the benefits of state licensing now provided other engineers. We request your continued cooperation in seeing that this is realized in every state. You can be of invaluable aid in this as you are in the other engineering professions. It is most gratifying also to see that nearly every college engineering group offers membership in honorary organizations to agricultural engineers.

The agricultural engineer has contributed, if not led, in engineering of agriculture—which not only reduces man-hours in crop production, but also reduces losses in production, provides storage for commodities, increases animal production through proper housing, and above all saves the productive soil which is basic to the life of a nation. The world's increasing need for food has emphasized the need for better trained agricultural engineers—that more food can be produced for all peoples—thus removing an important age-long disturber of world peace.

What Every Engineer Should Know*

By WELLER EMBLER

Head, Dept. of Humanities, The Cooper Union

I

It is my purpose today to present for your evaluation the ten categories of knowledge which should inform the humanistic-social education of the engineering undergraduate. These categories, together with their governing motifs, make up the body of knowledge of the humanistic-social branch of learning. For convenience merely, I shall present these categories in alphabetical order as follows: Civilization, Fine Arts, Human Relations, Language, Literature, Philosophy, Psychology, Science, Social Process, and Technics.

1. *Civilization*

In recent decades there have been scholarly and profound historical sanctions given to the idea that western civilization has rounded the curve of maturity and started on the downward path of decay and inevitable disintegration. Oswald Spengler's "The Decline of the West" disenchanted a good many innocent souls who had always thought of the historical process as a steady ascent from the abject and bestial to that far-off divine event when upright man should enter into a technological Garden of Eden. Latterly, however, the proposition of decay has given over to a much more violent notion which contemplates not slow senility but, coincident with the manufacture and use of the atom bomb, the utter and immediate destruction of western civilization.

Since we are so anxious to preserve it, we ought to know what we mean by "civilization."

The term civilization is a mighty abstraction, and it stands for an interacting complex of human values and symbolic monuments. To grasp the concept of civilization it is necessary to see how civilizations differ; how in the past they have struggled against one another and are still struggling against one another; how each is in its way a function of its religious belief; how the aesthetic expression of each is representative of its inner world-view; how changes have come about in each through technological invention; how a civilization's political and social ideals have evolved from deeply rooted unconscious urges of the race mind; and how social and political changes come about through contact with other civilizations. To grasp the concept of civilization, it is well to study specific civilizations; but neither the typical course in the chronological history of a single national state, nor a parrot-knowledge of names, dates, places, and events will serve. The typical history course is more likely to defeat the purpose of world understanding than to encourage it, since it places emphasis on isolated chronological facts rather than on related attitudes and inner meanings.

* Presented at the 55th Annual Meeting, A.S.S.E., June 18, 1947.

The authority of the leading historian of our day speaks out against a dangerous provincialism. In *Harper's Magazine* for April, 1947, in an article entitled "Encounters Between Civilizations," Arnold Toynbee looks into the future as far as he can see.

"By A.D. 4047 the distinction—which looms large today—between the Western Civilization, as an aggressor, and the other civilizations, as its victims, will probably seem unimportant. When radiation has been followed by counterradiation of influences, what will stand out will be a single great experience, common to the whole of mankind: the experience of having one's parochial social heritage battered to bits by collision with the parochial heritages of other civilizations, and then finding a new life—a new common life—springing up out of the wreckage."

Even at the risk of having only a superficial knowledge, the engineer of today ought to know something of the great world civilizations, of their motivating ideologies, of the struggles between them, and of their mutual diffusion.

2. *Fine Arts*

Music, painting, sculpture, architecture, the dance, and the theatre are among the glorious events of human experience. In themselves they are the evidence of man's search for power controlled in beautiful, delightful form. But they are also emblematic of an age and of a civilization's world-view. For those whose destiny it is to analyze and appreciate the fine arts rather than to create in them, not one but numerous approaches have to be undertaken, not in one course alone, but interspersed throughout many courses. Hence history must be concerned with fine arts, and so also must literature, psychology, and philosophy; in fact, as contributing to the building of intelligent human relations, as well as to individual self-knowledge, no category in this discussion should be unmindful of the importance of the fine arts. Courses in the "appreciation of art" altogether too often devote themselves to scattering about miscellaneous information on a few selected works of art. In these courses pre-professional students get the idea that "art" is some kind of bizarre creation which for some inexplicable reason rich people buy and sell, and intellectuals talk about at cocktail parties. Why he should decorate his professional career with such ornaments the engineer will never know. But out of deference to convention, the engineer looks at pictures and listens to music. Art appreciation courses may supply a kind of pleasurable, sensuous relaxation; educationally, they are beside the point. The function of analysis in the fine arts is much the same as in literature. The student ought not to be encouraged to be the passive recipient of mere sensations, he should be trained in approaches which will enable him to do *something* with aesthetic experiences, to make something emotional and intellectual out of them *for himself.*

Leading motifs in modern approaches to study in the fine arts are for the most part psychological and historical. The fine arts are symptoms of the inner life, manifestations of attitudes toward experience, sometimes for an individual, more often for a whole era. As such they are forms of communication; but they are even more. They are strategic ways of accepting or rejecting aspects of a world, not only in what they "say" but in their very structure and form. Important also for study is the aesthetic evocation of the subtle and powerful force of the irrational in

man, the force which brave reason deludes itself into thinking has been forever banished from human experience. Modern art has felt anew the sway of the pre-rational forces in man and has expressed them exultantly. Science and technics, says Carl Gustav Jung, have "attracted human consciousness to such an extent" that we have forgotten "the unaccountable forces of the unconscious mind." But they are there, and "not a few people, nowadays . . . are convinced that mere human reason is not entirely up to the enormous task of fettering the volcano." [1] Art does not let us forget these forces, and an understanding of them may yet prove of inestimable value to us.

3. *Human Relations*

That human beings live together and are dependent on one another is an empirical fact. If for no better reason, therefore, the cultivation of intelligent attitudes toward the social experience is of first importance in any educational program.

The category of human relations embraces many disciplines and many points of view; it cuts across all departments and all courses. But the cornerstone of any modern study of man in society must be a theory of "human nature." What one believes about human nature makes all the difference, and the many differing points of view must all be studied with care.

Whatever we believe, whether we accept the teachings of Plato or Jesus, of John Calvin or of Rousseau, of Percy Shelley, of Karl Marx, or of the late Adolph Hitler, we may be fairly sure that our belief governs our overt behavior and that we ought perhaps to look into our beliefs with some care. Indeed, it is quite possible that the lesson to be learned from the conflict of differing beliefs is that none is "true," but only that some are more consistent with our blessed hopes for mankind than others. Whatever man may be "really" is perhaps beside the point. We know only that all men are in the same small boat adrift in the dark, if not hostile, night.

Fundamental to all social thinking is the nature-nurture problem, and every undergraduate should be able to work with this problem critically. To begin with, he should know that biologists and sociologists alike are agreed that "heredity determines not traits themselves but responses of the individual to his environment." The decisions of heredity are not "implacable" destinies. "We can not change the heredity with which we were born, but in at least some cases we can choose an environment to which our heredity will respond most favorably." [2] And we know now that environment can be altered to meet most human needs.

Consistent with these beliefs, psychology has pointed out that there are psychological needs as well as biological needs, that there is a psychology of the city and a psychology of the country, that there are irrational factors in man's makeup that have to be taken seriously into account in any social organization, that the psychology of a mechanized society is different from the psychology of a crafts and agricultural society, and that strict conformity to the pressures of an environment may be as fraught with danger for both individual and community as total anarchy.

[1] Carl Gustav Jung, "Psychology & Religion" (New Haven: Yale University Press, 1946), pages 58, 59.

[2] L. C. Dunn and Th. Dobzhansky, "Heredity, Race and Society" (New York: Penquin Books, Inc., 1946), page 18.

There are other contributions to social thinking from other fields of investigation, and the undergraduate should also be acquainted with these. Cultural anthropology has given us the concepts of learned behavior, of cultural relativity, and of the diffusion of cultures, and has found the theories of inferior and superior races wholly untenable. Political scientists tell us that political theory and economic theory cannot be separated into different compartments, but that political thinking embraces all the departments of human behavior. And the best of the social thinkers have insisted that the ideal of objectivity is just as important in the investigation of social problems as in the investigation of purely physical phenomena.

It is necessary for the engineering undergraduate to know that in great measure man can control his social life and that when social change is demanded by intolerable conditions, he is not destined out of ancient and honorable habit to persevere in a learned culture pattern.

4. *Language*

A language is more than the words which make it up, for words by themselves are lifeless counters, of no more worth intrinsically than the gold in Kentucky. It is not until a word is used by a human being that it comes to life, as by a divine touch. A dictionary is not language. But a tale told by an illiterate, though all the rules of grammar may have been broken in the telling, is language.

The study of language has for some time been relegated at the college level to a course called Freshman English, the purpose of which has been training in the formalized ways of putting English word symbols together. But I think we ought to substitute the word "language" for "English" and drop the word "Freshman" altogether; for the concept of language involves infinitely more than the rules of syntax in English, and the study of language is never ending from cradle to grave.

The modern study of language begins with the thesis that language is inseparable from the people who use it. Language is a function of the psychological life of the individual user, and it is at the same time inextricably bound up with the cultural life of the group. It may be said that language is the instrument for reproducing meaning, the meaning having previously existed in the "thing" we refer to when we speak and in the cultural and psychological life of the speaker who makes the reference. (The study of how one person works with words constitutes the study of that person and not of language in general—a study of his psychological experiences, of his relationship to his community and to his time.)

There can be little doubt that language develops out of social conditions and in turn influences social behavior. Language is not just language, a something we have spoken all our lives without realizing it. Language is the language of the movies, of the laboratory, of the law courts, of James Joyce, of industry, of John Dewey, of newspapers, and of drawing rooms. It everywhere tells the story of the users. How it tells the story is what every student must know. To know what one wants to do and to know what is being done when words are used as the vehicle of meaning are the twofold aims of language inquiry. It is vital to the health of the speaker and to the health of the community to know how meaning is being reproduced, to see meaning, that is, in its cultural and psychological

context. It is necessary to know the purpose that selects the language of comic books, of newspapers, of political speeches, of scientific reports, of philosophical discourse, of poetry, of baby talk. The student reading is the student taking note of meaning and of the way meaning is conveyed.

The student writing or speaking is the student attempting to make language do what he wants it to do. He is writing "something for someone to read," or saying something for someone to hear.

In freshman courses in composition, drill in mechanics is not of first importance. The first rule of rhetoric is: Keep the eye on the object; and the student must be trained to look outward (at first, at least) rather than inward. To get the student into the habit of taking note of what is really happening, to teach him to focus clearly on the event or the thing and habitually to use language accordingly, is the aim of an education in language use.

5. *Literature*

There are teachers who feel that the social, psychological, and historical approaches to the study of literature are inimical to the beauty of literature. To these teachers, social analysis debases a work of literary art by lowering it to the level of everyday "facts"; and facts are somehow always ugly and sordid. To these teachers, the psychological analysis is a vulgar forcing of entrance upon the writer's private life and a slanderous soiling of his reputation.

To these teachers the historical method of analysis, which treats literature as symbolic of the age in which it was written, denies literature's high claim to universality, and, like the social approach, lowers a literary work to the level of transient events and ephemeral interests. Instead of having social, psychological, or historical implications, literature, to these teachers, is an absolute and unrelated experience.

The purpose of the study of any subject-matter is not only to know, but to be able to do something with what one knows. To this end, it is necessary to develop in the student an inquiring frame of mind, which is really a critical frame of mind. To be uncritical is to be nothing and to do nothing. The uncritical attitude is the parasitic and egocentric attitude, construing the world as "host," ministering to the comfort and pleasure of the guest. Great works of literature are a challenge, not a gift or an opiate. I am very much afraid that literature taught as "pure" and unattached expression encourages a receptive and passive attitude of mind, and passivity ought not, surely, to be the aim of education today. Moreover, the conduct of the work in the classroom ought to be such that the student is encouraged to do something with his material, to make something out of it.

Literature taught as the eloquent representation of the spirit of an age engages the student in a critical encounter from which he will emerge less passive and more intelligently inquiring. Literature taught as symptomatic of the inner feelings of the writer not only tells a truth—the truth about the writer—but truths about the incredibly complicated and incredibly wonderful structure of the human personality. Although the perfect society may have no need of literature—as Plato has said—the imperfect society obviously has. Literature by its very nature is functionally related to the social background. Literature as a criticism of life is nothing new under the sun. So

long as life in society exists, literature must always serve as the most vital commentary on the experience of human beings living together.

A great work of art is not belittled by a technique of analysis but only by little minds using a technique of analysis. We do not have to worry that curiosity will take the pleasure or the beauty or the nobleness out of literature. The beauty and nobleness of a great work are quite capable of taking care of themselves.

6. *Philosophy*

One of the famous philosophers of antiquity was Heraclitus of Miletus. Few words of Heraclitus survive, but of those that remain three are adequate to describe his philosophy: "All is flux," he said. Although removed in time by some twenty-five hundred years from Heraclitus, we understand him perfectly. The twentieth century is characterized by the displacement of energy and by the displacement of persons.

Yet this insistence upon a world in process, where time and space are inextricably bound up with motion, and change is of the essence of experience, does not quite square with our innermost intuitions. Whatever the submicroscopic world may consist of, whatever analysis of matter may yield in the form of atomic structure, to the naked eye, to the man ploughing his field, to the boy and girl walking hand in hand, all the universe has the aspect of essential permanence.

The purpose of older philosophers, and especially of those that in one way or another derive from Plato, has commonly been to find the permanent within the transitory; for to the intuition, the good life depends in large part on a constant awareness of an abiding reality, on values which are qualitative and enduring.

The purpose of more modern philosophies has been largely critical. And this purpose also derives from the philosophers of ancient Greece. It was Socrates the gadfly who annoyed the citizens of Athens with his insistent questioning. In the twentieth century A.D., Alfred North Whitehead has said that "Philosophy, in one of its functions, is the critic of cosmologies. . . . It has to insist on the scrutiny of the ultimate ideas, and on the retention of the whole of the evidence in shaping our cosmological scheme." [3]

I would have every undergraduate know something of each of these two purposes of philosophy. Readings in the great philosophers will acquaint the student with the sublime ideas of philosophy, and the right kind of instruction (the Socratic is still probably the best) will seek to inculcate in the student the skeptical frame of mind. In youth, at least, a clarity of vision, a freedom from importunate dogma, and a measure of trust in one's own intuitions is possible. Human beings are given to putting all manner of constructions upon experience. The perennial task of philosophy is to examine these constructions and to lay bare their basic assumptions in the everlasting pursuit of the good life.

7. *Psychology*

There is a notion current among those who have never made a formal study of psychology that the subject is a secret key for unlocking the mysteries of human personality for the purpose of manipulating other people. It is said that psychology will teach one how

[3] Alfred North Whitehead, "Science and the Modern World," "Preface" (New York: The Macmillan Co., Inc., 1946).

to get along with other people, which when translated means how to get out of others what one wants without having those others take offense. The many fakers who have exploited and perverted the findings of psychology have brought an unfortunate discredit upon one of the most important studies in a Humanistic education.

The critical motif of modern psychology is the hypothesis that the normal is a relative, cultural ideal and that aberrations are deviations from a theoretical standard. This means that psychology looks at behavior not as something standing by itself and ready for judgment, but as symptomatic of what is going on inside the individual or the group. Psychology examines the character of psychological needs and of psychological compulsions, which differ in different social orders. Psychology examines the nature of personality, of the learning process, of the effect of cultural ideals, and of habit.

However, psychology has grown out of, and is in a very real sense still, a subdivision of that ancient and august disicpline, philosophy. It has been said of William James, for instance, that "he approached life theologically but proposed to deal with it scientifically."[4] Since psychology investigates the conscious and the unconscious processes of the human mind, it does not always achieve to the larger measure of detachment afforded the biological and physical sciences. Therefore, psychology not only asks scientifically why people behave as they do, it is philosophical in that it attempts to promote social understanding and to guide the individual toward that wholeness of personality which is mental health.

8. *Science*

Except for a few fanatical science-haters, no one doubts the need for the inclusion of science in any undergraduate curriculum; and since an engineering education is primarily an education in scientific reasoning, it would be superfluous and vain for me to argue the importance of science. But I want to talk briefly about "science" from the Humanistic point of view.

Because it is analytical in its techniques, science has been called murderous and destructive; because it is detached and skeptical in its approach, science has been called the enemy of religion; because modern warfare has used the discoveries of science with monstrous and inhuman results, it has been sought out as the scapegoat for the guilt which modern man cannot wash his hands of; because science has made possible the technological successes of modern industry, it has been held up as the creator of Frankenstein monsters who feed on human beings.

Now indeed there my be scientists who are homicidal maniacs, and there may be scientists who are "atheistical." There may be scientists who love to fashion the bloody weapons of war, and there may be scientists without the slightest sense of human values. But of this I am sure: These inhuman traits are not to be found exclusively among the men of science. Einstein is not the villain of the piece. It is not "science" which is to blame for the ills of the world. It is, among other things, the use to which Everyman has put science.

Science has a passion for the repetitive and the predictable. Intolerant of caprice, science finds measure and or-

[4] T. V. Smith, "Modern American Philosophers" in "American Writers on American Literature," edited by John Macy (New York: Horace Liveright, Inc., 1931), page 364.

der in the facts of nature. Science ventures fearlessly to explore the unknown. Science makes mistakes, but because it knows its mistakes, it knows no guilt. Science is skepticism—it has to be shown. It will not believe what it does not see and hear. Science keeps its eye on what is happening, and has a fondness for the "irreducible brute fact." And in the application of its theories, science seeks to make the ideal practicable.

In other words, the scientific view of life like the aesthetic and philosophical is a strategic way of redeeming the world and experience. What I would have the layman know is that science is an efficient and fruitful method of reasoning, not an occult and mysterious ritual, and not in itself an ill-advised prying into perilous secrets. What I would have the engineer know is that science is not an ivory-tower kind of investigation set apart from human affairs, but a way of reasoning which is efficient and fruitful only in terms of its effect on human beings.

9. Social Process

To the soul of modern man life has the aspect of eternal mutability. Nothing abides, and with Heraclitus we agree that all is flux. The stars are transient in the heavens, and the atom is a nucleus of restless energy.

In nineteenth-century thought also, the idea of change was a part of the world-view. But in the nineteenth century, change was a phenomenon essentially systematic, and flux was an unfolding of events, and the working out of a premeditated or at least of an initially well-organized plan. The nineteenth century established for posterity the notion of social progress. That "history" marches steadily "forward" toward some far-off divine event was and still is a stock idea in the minds of many people.

The concept of progress had its birth in the eighteenth century where it flourished in the thought of brave new social speculation. In the nineteenth century, supported by technological invention and the expansion of empire, it came of age and was given scientific sanction in the theory of evolution. To the end that he may be abreast of the intellectual activity of his time, and most particularly that he may be prepared to apply a critical apparatus to nineteenth-century theories of progress, I would have the engineering undergraduate enjoy more than a nodding acquaintance with the ideas of social evolution.

Social theories of progress are inseparable from biological theories of evolution. In both history and biology the theory of evolution indicates development from simplicity to complexity, from homogeneity to heterogeneity, and from low to high organization. In the eighteenth-century theory of progress, society "ascends" of necessity from tribal superstitions to the social justice and social equality of the golden age. In the organic theory of history, civilizations follow a curve of development which begins with birth, describes a peak of maturity, and descends into senility and disintegration. In the dialectical-materialistic theory of history, human society, by discontinuous evolution is ever re-synthesizing toward the event of perfect organization. In the philosophy of "Becoming," each event springs full-fledged from space-time as a new creation. In biology, the Darwinian theory of natural selection postulates a struggle for existence among individuals. Individuals with

favorable variations will survive while those with unfavorable variations will die or fail to reproduce. "Thus natural selection will act constantly to improve and to maintain the adjustment of animals and plants to their surroundings and their way of life." [5] In nineteenth-century social thought the theory of natural selection was used as scientific sanction for "social selection," in which the fittest was understood as the shrewdest, thriftiest, and most industrious. In twentieth-century social thought the law of selection becomes in the hands of Alfred North Whitehead and other liberal thinkers support for the theory of universal social cooperation.

Problems of social causation, of the cultural lag, of social organization, of social planning, of crisis, of political and cultural change are all discussable today in terms of social dynamics. Actually the basic problem of social dynamics is not so complicated as it looks. Fundamental to our world-view today is, as I have said, the belief in the inevitability of change. It is true that social ideas are subject to change. I think we may assume that no social order is absolute. But some social orders are infinitely nearer the heart's desire than others. We cannot legislate for eternity; nevertheless we can direct the evolution of our culture if we wish. What I would have the undergraduate know is that theories of the historical process are constructions which the human mind has put upon experience—that they are not necessarily "true." Sometimes they are sheer intellectual exercises; but mostly they are ways of articulating our deepest hopes for social well-being.

[5] Julian Huxley, "Evolution, The Modern Synthesis" (New York: Harper and Brothers, 1942), page 16.

10. *Technics*

In the ASEE "Report of the Committee on Academic Tenure, Professional Service and Responsibility" [6] the authors recommend that engineers study the ideals of Thomas Jefferson as the basis for an ethic for engineers. This is a curious but not uncommon inconsistency. Very nearly everyone admires Jefferson for his humanity; but Jefferson's philosophy sprang from a profound conviction that the agrarian way of life was the best way of life. He did not approve of the industrialization of the American nation. He wanted to revive the glory that was agricultural Greece. If I remember correctly, he said that the great cities of the North with their growing factory systems would breed Roman mobs, ignorant of the responsibilities of the democratic way of life, and the prey of demagogues.

But whether or not Jefferson approved of industrialization made little difference. Willy nilly, the industrial revolution was subsequently to shape the destiny of the western world in a far more thoroughgoing fashion than the physiocratic ideals of Thomas Jefferson. The American nation became a mechanized one, and American culture was formed out of the unbelievable industrial successes of the nineteenth century. Our attitudes and our values are conditioned by the technological environment in which we live.

New sources of energy whatever they may be or from wheresoever they may come are discoveries of inestimable influence on the cultural life of the people who use them. Henry Adams in "The Education of Henry Adams" has already estimated the difference be-

[6] *Journal of Engineering Education*, 36: 601–11 (June, 1946).

tween the power of the Virgin of Chartres and the power of steam. "All the steam in the world," he said, "could not, like the Virgin, build Chartres." It is true that steam could not build Chartres Cathedral, but the ideals of a commercial society, part and parcel as they are of the power of modern technology, did build the skyscrapers of the great cities of America.

Mechanization has meant mass production, which in turn has changed our minds about many things. Mechanization has meant a new type of human labor, new wants, new satisfactions, new visions—in short a totally new historical predicament, with, some say, an attendant dehumanization of man. Mechanization has meant changes in social theory, in social planning, in social organization, and in economic experiences, changes which would have been unthinkable to our grandsires. But mechanization has even deeper effects on our way of life. Mechanization has brought into being new theories of space, mass, energy, and matter, having ultimately a profound religious significance. It is important for the engineer to know that by the very nature of his work and his technological inquiries he is shaping the destiny of our cultural complex.

II

And now I must dwell for a moment on what these categories are not.

These categories are not to be thought of as "courses" with a specific subject matter. I am not speaking in terms of courses, credit hours, or departments. I am concerned only with ideas and with attitudes of mind. For instance, one of the categories is "literature." I am not speaking of "courses" in English or in American literature. I mean that there is a wonderful way of thinking and talking about life which is literary rather than, say, journalistic or scientific. I mean that undergraduates ought to know something about this way of talking about life. In other words, I am thinking not so much of subject matters as I am of points of view. The concept of cultural relativity, for example, should become for the student one of those pivotal points of reference in the same sense in which a prejudice is a point of reference, or any cherished belief.

The concepts which form the compendium of knowledge should be understood as the essential equipment for a man of the world. Under no circumstances are they to be thought of as tools to a profession or trade. These categories are the common body of knowledge which inoculate the student against the disease of provinciality and save him for the world and for himself.

I do not think of these categories as departments of knowledge to be "studied" exhaustively in seminars, so that the student may become a "specialist" in any one. The danger of superficiality is not so great as we make it out to be. It is enough in some respects to know that these categories exist. It is enough to subject students to them if for no other reason than to broaden the undergraduate's area of tolerance for ideas and points of view. Just to know, for instance, that there is a psychological life for each one of us and that there are psychological needs as important as bodily needs and that there is an efficient way of talking and thinking about these needs is a long stride away from a foolish complacency. The greatest thing we have to fight as educators is bumptious ignorance of the areas of investigation (from surrealist painting to atomic physics) in

the thought of the modern world. It is necessary on occasions to appreciate one's own ignorance. To be intelligently critical one must know at least that he does not know, but that there are ways in which he can find out if he will.

III

Thus far I have been talking about the student. What shall we say about the teacher? It is the perennial challenge of the teacher to win his students over to a fondness for the material with which they are working together. How shall this be done with engineering undergraduates in the Humanities? It is not accomplished by treating engineering students as though they lacked the graces of drawing-room life and needed to be decked and ornamented with "cultural" embellishments. Even young people do not like to be patronized. It is not accomplished by preaching sermons on the engineer's alleged ignorance of social issues and of social values. It is not accomplished through drill on purpose to the accumulation of miscellaneous information. And to the eager young minds of students today it is certainly not accomplished by dusting off the notes which were gathered twenty years before in preparation for the professor's doctoral dissertation.

It should be obvious by now that general education in the Humanities calls for specially trained instructors who are interested primarily in teaching and not in research, who are interested in today's world first and yesterday's world for what it has to give to those who are young and alive, who believe that critical analysis is a vital approach to any subject matter, who believe that vested interests in departmental subject matters are at least dissolved. The new teacher must himself have had a broad, general education, and he must be as fearful of one-sidedness in himself as he is fearful of onesidedness in his students. The new teacher will not want to spend his time policing his special preserve. He will prefer to venture into many fields of learning with an open mind and a critical eye. A "teacher" is something more than a repository of knowledge of a small field of investigation. A teacher teaches students not the contents of a textbook. And in this respect, the good teacher is fully creative, for when he talks about ideas with his students, he brings those ideas to life in a new context and a new synthesis.

The content of a course is soon forgotten. Even a skill is diminished with lack of use. The teacher's success is measured by the attitudes which he inspires in his students.

IV

"The uncritical life," said Socrates, "is not worth living."

Socrates was a teacher, and he knew what he was talking about. Education is, or ought to be, systematic criticism.

There are some people who think of criticism as mere fault-finding, and they have no use for it, especially if it attacks their own self-interests. But criticism as Socrates meant it is not fault-finding. It is the process of repairs and renewal in social life. And social life, any more than human life, cannot survive without repairs and renewal. Indeed, today it is necessary to emend Socrates' statement to read: Without criticism there can be no life.

Education—education of the whole man—believes in criticism as a process which is always going on, and always going on from within. Education is not interested in patching the surface

wounds, because it knows that patching is ultimately only makeshift; and education has to go deeper than makeshift. Education is not concerned with changing the content of a course, or with adding a new course to the curriculum, or with reorganizing the conventional courses into a new pattern. All this is mere evasion. Education is concerned with attitudes; and attitudes are repaired from within outward, so that what is achieved is a new beginning, a commencement.

It is inevitable that if an organization is ill it should be repaired. A civilization is renewed by education, and this means by the education of people, of each individual person. People are the parts of a civilization, and it is by changing their minds that the civilization survives. Sometimes people's minds are changed for them; but we do not like that to happen, and we would rather that intelligent criticism should persuade people to change their minds.

Civilization will survive, even if they have to arise from their ashes. But we do not want to play the phoenix; we want to endure and change and endure. Now it would be a crime against nature and the inevitable to hinder or to thwart renewal. And the wise man will want to take part in the inevitable, because it is in this taking part that he will find his greatest happiness, and he will wish to play the role of prophet and be forever forward looking.

In education today we have no choice but to do what we must do. We must train for social intelligence. With relentless logic, world events and world ideas are moving toward the obvious necessity of social enlightenment for all.

What is This "Culture"?*

By A. M. BUCHAN

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It is, of course, a high honor for a teacher of literature to be asked to address a group of engineers and engineering educators. It is also a strange portent. Until recently, the relationship between the man of letters and the engineer has not been particularly cordial. The literary man, patron of the fine arts and something of an aesthete, has looked down on the engineering student as a sort of barbarian; in the words of Professor Gilkey of Iowa State College, "an indispensable but uncouth, smelly and ill-dispositioned" creature, "a greasy illiterate individual who sure can use a monkey wrench and a slide rule but who is naught but an embarrassment and a liability in polite society." The engineer has responded with a similar contempt. He himself is rough, masculine, practical, scornful of fine phrases and sentiments; and he despises the man of letters as a sissy who talks a language too nice for ordinary people and indulges in attitudes more appropriate to women than to men of affairs.

Recently, however, a change has taken place in this relationship. The engineer, going into a world only part of which he makes, hungers for a polish and social ease that he thinks he recognizes in his professional companions, the doctor and the lawyer. Anxious to be thought a gentleman as well as a practical fellow, he turns to teachers of literature and history and even philosophy to make up the arrears of his "culture." Overnight he has become aware of the explosive core of the world he has made and he wonders—rather humbly, one believes—if he has the spiritual stamina to keep that world intact. On the other hand, the teacher of literature is not content any longer to accept from the engineer the thousand and one items of civilized comfort that make it possible for him to pretend to be a gentleman. This barbarian gets things done. He moves rivers and mountains, and not by faith. He erects great machines and taps unimaginable sources of power to drive them: he makes all old conceptions of tragedy seem inadequate. Is it wise to turn this powerful creature loose on civilization without informing him about Milton's belief in the ways of God or Shakespeare's conviction that

> ". . . it is excellent
> To have a giant's strength, but it is tyrannous
> To use it like a giant"?

The engineer, being practical, has already taken the problem in hand. Several reports have been drawn up about the training of students, and the engineer's hope for himself is reflected in what he wants done in the school. The two most extensive reports, the 1940 one on Aims and Scope and the 1944

* Presented at the 55th annual meeting, A.S.E.E., Minneapolis, June 17–21, 1947.

one on Engineering Education after the War, sketch rather clearly the outlines of the cultural pattern that is desired and the responsibility placed on the teachers of humanities for the new design. The statement of the 1940 report was admirable, and though it has been quoted many times, it is worth summarizing again: it recommends the development, in students of engineering, of the "ability to read, write, and speak the English language effectively." It suggests that these students should be able "to understand, analyze, and express the essentials of an economic, social, or humanistic situation." It sets up the goal of the development of an "adequate concept of the duties of citizenship in a democratic society, an acquaintanceship with the enduring ideas and aspirations which men have evolved as guides to ethical and moral values, and an appreciation of cultural interests lying outside the field of engineering."

This statement of aims contained in the 1940 report was repeated in other phrases in the 1944 report and has been approved repeatedly by educators and business executives in the JOURNAL and other magazines. Professor Bronwell of Northwestern, for instance, in sumarizing the 1944 report, listed these among the aims of an engineering education:

the "inculcation of a philosophy of life and a set of values including a professional attitude, moral and ethical principles, a sense of responsibility and eagerness to contribute to the advancement of society and the profession"; with an "appreciation of the higher forms of expression—literature, art, philosophy, and music."

Professor Elliott Smith of Yale drew up this version of the aims:

"They are to prepare the engineering student to learn from study and experience throughout life to serve society, to live his own life well, and to work well with others."

Mr. Hazeltine, a consulting engineer of New Jersey, having in mind the same reports and purposes, wrote about a training for engineers that would "provide the fullest understanding of the contemporary world," and that, while including the timeless basic sciences, would "link with the past through courses in history and literature." In the May JOURNAL, Professor McEnany of Rice Institute was requoting from the 1944 report and emphasizing how important it was for engineers to be introduced to the great books and the great ideas of mankind, as well as how necessary it was for them to make "their own satisfactory adjustments to personal and social situations."

With all respect for these excellent reports and for the many favorable comments on them, I'd like to suggest that the aims set are far too high. What they demand is not a kind of education for engineering students or a form of culture for engineers themselves, but a form of salvation. If these exalted aims are to be retained, the question before us must be stated in different words. It should not be "What is this culture that engineers should cultivate?" but rather "What must the engineer do to be saved?" These aims can scarcely be presented as realizable in terms of fallible human beings, crowded curricula and quite imperfect teachers of the humanities which, presumably, will be the scriptures of this gospel: they seem to consider the process of education as Bunyan considered the progress of Christian—a pilgrimage from a city of destruction to a celestial city. And no education, certainly not the literary kind with which I am reasonably fa-

miliar, is able to bear such a responsibility.

Let us look at one or two of these stated objectives and see how even the best forms of training fall short.

One excellent goal proposed is "development of the ability to read, write, and speak the English language effectively." This has been, as you know, a goal of English departments from the old days of training in rhetoric to our up-to-date practices—not noticeably an improvement—of theme-writing and training in speech, and yet with all of our experimentation we lag far behind the goal set. Businessmen still complain bitterly about the illiteracy of our students, and neither our talk nor our platform speaking does much credit to teachers of speech and composition. It may be that this ideal of an "effective" use of the language, in speech and writing, has been fostered in the tradition of the great writers and the great orators, and that, trying to do too much, trying to make artists of language out of people who will never need more than a craftsmanlike handling of their tongue, we miss the near goal of literacy in seeking the far one of mastery. It is this immediate problem of the higher illiteracy that we must work at, doing what is feasible to loosen and sharpen the tongues and pens of engineers as of other professional folk. Let us recall Dr. Burdell's temperate statement given to this group last summer:

> "Any program of college studies quite obviously needs to provide for training in the use of English and for the development of acceptable speech habits. . . ."

"Training in the use of English,"—there is a manageable aim: and "the development of acceptable speech habits" comes within the reach of a college program. However, among these acceptable habits, as a mark of the culture of an engineer, may be a break with the abundance of mere fluency that marks politics, the church, and all too frequently the university as well. Maybe the engineer, unlike the columnist, the politician, the minister, and the "liberal" professor, ought to cultivate a bare speech, opening his mouth only when he has something to say and saying it like the stroke of a hammer.

A second aim proposed is the one of "understanding and expressing the essentials of a social or human situation." Here is one of the toughest of possible assignments. The simplest of social situations, such a one, for example, as reckoning the number of dollars an hour that a carpenter earns, are hard to understand, especially if one gets down to essentials. There are very few of us, besides, who are at all competent to explain or analyze even a rudimentary human situation. The social worker, the psychologist, the psychiatrist and the priest toil overtime at this job and are perpetually baffled. Let us take the situation of the veteran making an effort to adjust to study, to teachers such as we are, to a life suddenly stripped of excitement, and to the job of making ends meet: who is fit to understand or to explain it except in fragments and in the mood of a totally inadequate pity and respect?

It may be said categorically that no social or human situation is ever fully understood or expressed, and certainly we have to be satisfied with much less in our hopes for engineering students. An instance from the field of literature will help make the problem clear. You have probably heard that for some three and a half centuries scholars have been debating whether a certain prince called Hamlet was mad or not, and

students of drama must still try to explain to conventionally-minded people the wisdom of Dora's leaving her husband at the end of Ibsen's "Doll's House." These and other literary situations are fixed, recorded on the page, and unchanging except by the critics' imagination: how, if these static problems are still being debated, can we hope to understand or explain the fluid, complex problems of any man's day?

Once again, instead of the idealistic words of the reports, I'd like to refer to Dr. Burdell's admirable emphasis, not on ready-made or easily-got solutions but on "the development of a problem-solving ability." The more precisely these problems are examined, the less apt is any cultivated man to suppose that he fully understands or can explain them.

In connection with this, an article appeared not long ago in the JOURNAL. It was entitled "What Industry expects of Engineering Education after the War" and was written by an executive of a large electrical company. This paragraph was a most interesting one:

"No matter how fine a man's technical qualifications may be, in order to take an important place in industry today he must know people as he never knew them before. He must be able to differentiate between the good and the bad, the true and the false, the worthwhile and the unimportant. He must study and know the reactions of people just as he studies and knows the reactions of material things."

In a sense this pronouncement is thoroughly sound because it brings into focus the importance of personal relationships in industry. As was brought out from the questionnaires summarized in *Mechanical Engineering* for April last, business men want graduate engineers to be men as well as technicians, men who are secure in themselves and so free to meet and work with other men. In another sense, however, these sentences from the article are quite frightening. For they imply that it is possible to know the reactions of people as one knows the reactions of material things. They suggest that a man behind a desk in an office can tell whether another man, sitting before him being interviewed, is good or bad, true or false, worth something or worthless. They imply that a competent executive is able to size up a human situation and not only understand it fully but feel confident enough to say, "I'm sorry. I can't hire you. You're no good!"

If there is one lesson in great literature—and there are fewer such lessons than many readers suppose—it has to do with the menace of this form of judgment. In the 14th century in England, a writer by the name of Chaucer passed a number of his contemporaries through his hands. Very few of them were estimable, because the churchmen were neither holy nor faithful to their charge, and the professional men, like such men still, were more concerned with the main chance than with the good of society. And yet this writer, a wizard with words and rhymes, had a deep liking for these not-so-good characters he sketched in the "Prologue." With more of the spirit of inquiry in him than of the spirit of judgment, he had a broader sanity about the society of his time and about human nature than almost any other observer. Better than most people he understood and wrote about social and human situations, but he was certainly the last to refer to his fellows as good or bad, true or false, worthwhile or worthless. And this fine suspension of judgment that he and others among the great men of letters have exercised

in recording the stories of men, is still one of the marks of the cultivated person. Whether another man is useful or not for his immediate purpose—this verdict the engineering executive is fully within his rights to pass, but whether the man is good or bad is a judgment of a totally different order of value, and few of us are in a position to exercise it.

One more of these aims, as set out in the official reports, bears mentioning, because it is in line with a noticeable trend in colleges of liberal arts. We have been hearing a great deal recently about great books and great ideas, and lists of the books containing these portentous ideas have been drawn up by various scholars who fancy themselves as authorities. No one, of course, who has studied Plato or Spinoza or John Locke or John Stuart Mill would ever seek to underestimate the power of these men's thought, and this is probably why the committees on engineering education recommend an "acquaintanceship with the enduring ideas and aspirations which men have evolved as guides to ethical and moral values." Yet it is still true that the distortion of a great idea is a thoroughly evil idea, that propagandists use noble ideas for their own mean ends, and that a half-understanding of a great book has been too often in the history of the world the greatest obstacle to progress. It may be wiser, one imagines, not to mention Immanuel Kant at all than to leave students with the notion, easily taken from Kant, that the moral will has nothing to do with living emotions. If the great ideas are to be taught so that they will fit into a broad and useful cultural pattern, they must not be handled in the off-hours of the curriculum, or by instructors whose knowledge of them has been picked up by the casual familiarity of a course in the "great books."

It begins to appear, then, that some of these cultural aims, admirable as they are, may readily be overstated. After all, what concerns myself and other teachers of literature is not in essence the moral welfare of the engineer, which might conceivably suffer at our hands. We are allowed a fraction of about ⅕ of a four or five-year curriculum, and into those few hours of teaching and conference we can not be expected to cram the skills of writing and speech, the knowledge of great literature, and the foundation of a sound philosophy of life.

One or two precautions, in fact, are in order about literature as it is taught.

Though one regrets having to repeat the charge, it is true that the majority of courses in literature, as given in liberal arts colleges, will have no cultural force on students of engineering. These courses were designed and are being run for specialists, the specialty being literary research which, in its own fashion, is as technical a pursuit as the testing of materials or the principles of acoustics. Unfortunately even the so-called "survey" courses in literature are taught by men who are compelled, by the rigors of the academic game, to think more highly of literary and textual criticism than of whatever other values great literature possesses. Foisting these courses on engineers will likely breed a firm distaste for literature and prevent the engineer from ever meeting, on a common ground, the man of letters.

The study of literature, too, is unlike many other studies. One does not acquire a knowledge of literature as one absorbs by persistent effort the facts of history, let us say, or the formulae of chemistry. One grows up with

books, as one grows into friendship; and so to grow into a subject generally takes more time than administrative officials are willing to dole out. Slow careful reading, quiet and persistent talk, the trick of coming back again and again for another reading of a familiar passage—these are among the habits by which literature passes into one's bones and sinews. And they are habits difficult to foster by emergency changes in curriculum.

Another point must also be made. Although as a lover of literature I hate to make the confession, the influence of great literature is not, as has been commonly assumed, either certain or universal. A man may be too stupid or too busy or too deeply immersed in facts or too much of a propagandist ever to appreciate the plays of Sophocles or Shakespeare or to sympathize with Thoreau's flight from the world of affairs to Walden Pond. Because some books are great is no reason for supposing that they furnish all the answers. Literature, in fact, poses more problems than it solves, and it maintains, persistently and with absolute assurance, that we cannot, as the executive proposes we should, "know the reactions of people as we know the reactions of things." To the last explosion of the last atomic bomb, man will have in him, say the great writers, a quality that is imponderable and not to be measured by the finest instruments of the laboratories. For anybody, therefore, who likes to live with certainties and who wants his culture with the union label attached, literature offers little. It offers fear and humility rather than arrogance and display.

With all of its inadequacy as a gospel, however, it may have something to offer the engineer. It has, inherent in its nature, the capacity to help "liberalize" a man's attitude, and for this alone it is worth knowing.

Two recent interpretations of the word "liberalize" are so good that I must call them to your attention. One was made by Dean Hammond in a paper he read two and a half years ago. He asked:

> "What does the word 'liberalizing' mean? It is often discussed in terms of the addition to an otherwise narrowly specialized program of a cultural element comprising such non-technical subjects as history, economics, and literature. . . . The assumption that this means alone will serve the desired purpose appears to be based in part on the premise that technical and scientific subjects have an inherent lack of cultural elements. . . . This assumption is utterly erroneous. . . . Instead of such a restricted conception of the liberalization of technical education, we imply the broad purpose of developing among students understanding and appreciation of the world around them in its various aspects—social, economic, political, artistic, moral. . . ."

The other explanation was given by the Chairman of this committee at our meeting last year and was published in the April issue of the JOURNAL. It holds up to the engineer the ideal of scientific humanism, a marriage, as Dr. Burdell says, "of science and the accumulated culture of the past." In the schools its worth must be judged by what happens to the individual graduate, and it is measured by his ability to gain from all of the disciplines some capacity to live intelligently and well in the society of which he is a member.

From these interpretations may be taken a conception of a culture that is not adventitious, not a frill only, not the gilding on the lily, nor the silk hat on one's head, nor the use of fine, bright words only, nor the ability to quote from works of literature or to

recognize a tune played. Any or all of these may be part of it, but in itself it is, to use the mathematician's term, a "function" of a man's job, if he has a code to keep and standards by which his product may be judged.

We might trace the emergence of this conception of culture about the time of the Renaissance in the 16th century and its growth since then alongside a rising industrialism and a gradual broadening of democratic attitudes. For the moment, however, let me stick to my topic of literature and try to indicate briefly the connection between the books I read and the job of living that each of us must do. For only if that connection is real and immediate will literature have any worth as a means of culture.

Let me begin with a personal incident. This last spring, as one result of an overcrowded campus, I found myself lecturing to sixty students about great poems in English literature. Most of the sixty were veterans, and, as we discover, they refused to take my comments on faith. We were looking at Shelley's "Adonais," that fine tribute of one poet to another, and there came the need to examine the lovely speculative passage in which Shelley asserts the immortality of his young friend:

> "He is a portion of the loveliness
> Which once he made more lovely."

One of the boys raised his head and asked: "But how does he know? How can he be so sure? And why should we bother anyway about Platonic ideas in this practical world of ours?"

So I pointed out as best I could that many great writers have speculated about the worth of man's life and about the possibility of its being more than mortal; and I suggested that from some of these speculations there might be transferred to one's own life a sense of dignity and worth it would not otherwise have. A few days later the lad dropped into the office. He began to talk. "Perhaps," he said, "this thing I'm doing, this studying for a degree, would seem to be worth more if I could see a point in it." I agreed, of course. "And perhaps," he went on, "what Shelley was trying to do was to see some point in the death of a friend. That's hard, because death is a meaningless sort of thing. Is that what the poet does all the time—attach a meaning to the meaningless facts of human life?"

What this lad had inadvertently blundered into by means of "Adonais" is the insight that is the very core of culture. By some process of intelligent sympathy he had learned to understand the fine thought of another man; and, in a small way and without at all accepting Shelley's idea, to apply the same process to his own circumstances. In our quest of cultural values we follow the same road. We search continuously for fuller meanings in the routine job and in the aimless, undifferentiated incidents of human experience.

In order to try to make literature have some such value for students of engineering, I'd like to see started in all schools, in addition to courses in writing and history and economics, at least two in literature. One would be a reading course of a kind we have experimented with in St. Louis. The reading-list will include some of the so-called great books and a good many, too, of the lesser books that are not so apt to be misunderstood. The students must have time to read and regular meetings with a teacher who keeps from talking too much. If the books are carefully chosen, the students, as

they speak about them, cannot help but absorb some of the "meanings" I was referring to: Machiavelli's plan for running a state, for instance, or Walter Lippmann's notions about foreign policy, or Shaw's views on marriage and the relationships of the sexes.

It is not essential that the range of reading be wide. A student should not by an encyclopedia or an authority on literature—I doubt if anybody should. The one thing expected of him, and the only real sign of culture breaking into the course, will be his willingness to grasp another man's interpretation of a few of the miscellaneous facts of experience, and the measure of practice he has in talking about it.

The other course might be called "The Values of Literature" and it will not attempt to cover any large quantity of great books or any specified amount of material. It will introduce engineering students, by means of lecture and discussion, to one or two of the great literary stories of the past, a few of the inspired social documents, and a small number of the treatises that have given expression to the trends of human thought. Its chief purpose will be to explain, as directly as possible, what literature is and does, and how its statement of meanings is as important now as when it was first given. If such a course is taught well, no student should be able to deny—as sometimes they are encouraged to deny—that literature has value. Fragmentary as any such course is sure to be, the engineer should become aware that *man and society have interest and significance only as they have been given these out of the passion and desire with which the arts are filled.* It should stimulate a little of what William James has called "the feeling for a good human job anywhere, the admiration of the really admirable, the disesteem of what is cheap and trashy and impermanent, the sense of values . . . that is . . . the better part of what men know as wisdom."

Correlation of Mathematics and Electrical Engineering Courses*

By C. G. BRENNECKE

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The title of these remarks, as well as the calling of this conference, implies not so much an emergency need for improvement of correlation between instruction in Mathematics and instruction in Electrical Engineering, as a recognition of one of the growing pains of a still young and rapidly developing field of study. There is, and always has been, correlation between the two fields, but the mathematical needs of training in electrical engineering change and grow almost overnight, on an academic time-scale at least, and there is therefore need for continual reexamination and rearrangement of the techniques of furnishing the aspiring student with the mathematical foundation he needs.

This same need exists, of course, wherever fields of study are paired in the education of a man or woman. One need only mention the importance of physics to all branches of engineering, the importance of geology to the mining engineer, and of economics to the student of business, to make the point. In the broader sense, the need for correlation arises from the rigid departmentalization of American higher education, so efficient and convenient for administrative purposes, but so frequently ineffective in achieving an integrated education.

Historical Development of Analytical Methods in Electrical Engineering

As a major field of study, electrical engineering is scarcely fifty years old. Indeed, just about the turn of the century, in the few technical colleges existing at the time, it was emerging from the state of being a few physics courses in "Applied Electricity" or the like. When one realizes, however, that electric lighting and the telephone did not appear as commercial possibilities until 1880, that electric motors were scarcely used until 1890, that in 1895 the great controversy over the practicability of alternating current and the transformer still raged, it appears that the study of electrical engineering appeared nearly simultaneously with the first demand for electrical engineers.

The presentation of the theory of electrical circuits and machinery, until about 1920, tended to be strongly "practical" (*i.e.*, non-mathematical) and descriptive in nature. With a few significant exceptions, the standard texts made use of little more than the simplest algebra for direct-current considerations, and trigonometry for the symbolic vectors necessary for the un-

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derstanding of alternating current phenomena. The calculus was carefully avoided, even in discussing effective current values.

The influence of Charles P. Steinmetz was great in altering this condition. His convincing demonstrations of the convenience of using complex numbers to represent the symbolic vectors of electrical theory were largely responsible for making this method standard. His work on transient phenomena and on oscillating systems made the need for studying such matters obvious. His book "Engineering Mathematics," published in 1911, was a forerunner of many similar works which have appeared since, and contains material which even today is of interest and importance to students of electrical engineering.

The development of analytical techniques has accelerated rapidly in the last twenty years: intensive study of electronic devices and circuits, of circuits with distributed constants (in both the steady and transient states), of radiation, of wave guides, of closed-cycle control systems, all have been recognized as worthy of intensive treatment. These subjects and others have come to employ mathematical methods whose very existence engineering teachers and students once blissfully ignored. It is only reasonable to anticipate still further development of the same sort.

Shortcomings in Correlation

An all too common experience of teachers in junior and senior electrical engineering courses is to encounter, in class discussion, the need to use some simple bit of mathematical lore such as Euler's Theorem, or Maclaurin's Theorem, or hyperbolic trigonometry, and to find their students staring open-mouthed and ignorant, and swearing that they never had encountered this particular piece of foul black magic before. Previous knowledge or inquiry then convinces the professor that this is not the case: that the students *have* studied the topic in question in one or the other of their mathematics courses, but that they have either temporarily or permanently forgotten it completely.

The "recall," to borrow a term from our friends the psychologists, is not there. There has not been the desired carry-over from mathematics courses to later engineering studies. Why? At this point the recriminations begin.

Failure to Use Engineering Examples in Mathematics Courses

This is perhaps the most common criticism leveled at the mathematicians by the electrical engineering professor. "How," says he "can students be expected to realize the importance, to them, of the mathematics they are studying, if the applications are not made clear by example?" The beleaguered mathematician points to some problems involving electrical units in the text he is using, asks pointedly whether he is expected to be an engineer as well as a mathematics teacher, and, perhaps, inwardly resolves that the most useful examples are still those that begin "differentiate the following equation."

Close correlation, by the methods suggested later in this paper, is the only cure for this fault. It will require cooperative effort as well as criticism on the part of the engineering staff, and labor over and above the call of duty on the part of the mathematicians.

A most wholesome trend is exhibited by certain recent texts, such as Smith, Salkover, and Justice's "Calculus." In the latest edition of this work, nu-

merous two-stage problems are included, in which students are given certain data and facts, from which they must formulate an equation, which is then to be solved. These are "practical" problems in the best sense.

Overemphasis of questions of rigor on the part of mathematicians, at the expense of time better used in considering the applications of the theorems in question, is another criticism often made by the engineers. Such overemphasis, besides wasting time, is cited as responsible for the student's belief that mathematics is an intellectual exercise of little or no practical utility.

Here one cannot help sympathizing a little with the position of the mathematicians. They are specialists, after all, in their field, and to them it is more than a tool for technology. One might hope, too, that the better student will be impressed with the importance of mathematics as a system of logic good for his mind and character, to the extent that he will appreciate and honor even its "impractical" features. It must not be forgotten, however, that the primary purpose of his study is the acquisition of a weapon for the attacking of technological problems.

Relative emphasis of mathematical topics should be proportional to their later use in engineering courses. It is manifestly impossible, of course, to assure this completely, since it would necessitate among other things that each electrical engineering professor present any given topic in exactly the same way as each of his colleagues. However, steps can certainly be taken to approach the unattainable end: if the relatively few derivations and analyses, involving the calculus, essential to a first course in alternating current circuit theory, were known to the mathematicians preparing the students, the differentiations and integrations involved could be stressed at the expense of other forms less important in a utilitarian sense. Similarly the simple differential equations used in an introductory course in transient theory, or in calculating the mean free path of a particle in a gas, or in beginning the analysis of a transmission line, should be known to the mathematics faculty.

On the other hand, it could be pointed out to mathematics faculties that non-convergent series are of no real use to an engineer, and that for men who will at best riffle the pages of their integral tables whenever they encounter a form that looks tractable, the need to spend long stretches of class time discussing integration by substitution of a new variable is not great. The present trend, one is glad to note, is to introduce but not emphasize such topics.

Failure of Electrical Engineering Teachers to Make Full Use of Mathematics

This criticism is valid enough to begin to even the score. There is scarcely a large department of electrical engineering which does not number among its staff one or more who prefer the roundabout graphical or descriptive approach to the concise derivation involving the calculus or higher mysteries. The cause for this, one cannot help suspecting, lies chiefly in the shortcomings in the mathematical background of the men concerned. The argument often raised: that a descriptive approach makes it easier for the student to comprehend the physical facts involved, is untenable, in the opinion of the writer. To cite a case now happily historical rather than current, the writer was dragged through a maze of arithmetic designed to demonstrate,

by squaring and averaging selected ordinates of a laboriously drawn curve, that the effective value of a sinusoidal alternating current was 70.7 per cent of its maximum value. Since he had previously learned how to integrate a squared trigonometric function (or rather, how to look up the integral), this procedure served to impress him neither with the exactness of engineering proofs nor with the wisdom of the academic overlords who had foisted all that calculus on him. Certainly, avoiding the integration did not further education in this case.

The problem in this case is almost wholly an internal one for the electrical departments. It is to the credit of many previous efforts at coordination of educational work that it is also a rapidly disappearing problem, and as younger men, who have profited by the advances in technical education which this Society symbolizes, take their places on departmental staffs, it will be a problem of the past.

Tendency for Electrical Engineering Teachers to Teach Their Own Mathematics

This is perhaps the opposite side to the problem just discussed. Where special mathematics is necessary to the development of a particular electrical topic, and when the teacher has a natural facility in mathematics, it seems to him natural and appropriate to develop the mathematics in the electrical engineering course. In this way he is assured of a fresh and complete development, done exactly as he requires it.

The most elementary example of this sort of thing is the case of complex numbers and their algebra, as used in alternating current theory. The textbooks in this field now generally include a little summary of the subject, with examples, very convenient to use. On a higher level, one finds the instructor in electrical transients lecturing on operational mathematics, and the course in electromagnetic field theory beginning with a week or two of vector analysis.

This practice cannot be condemned as wholly bad—certainly not by the writer, who indulges himself in it to a fair degree. However, when it comes to a point of requesting mathematics departments to desist from any mention of such topics, departmentalization rather than correlation is being served. The better solution lies in taking up each such disputed topic in turn, and by agreement deciding on the best method of handling it. For example, in the case of complex numbers, the writer feels that several successive discussions will help enough to justify the time spent, and may indeed be essential. Thus, first instruction in this topic should be given in a trigonometry course, either in high school or college (or both), and the electrical engineering instructor should not hesitate to repeat it in full.

In other cases, local conditions should determine the division of effort. At North Carolina State College a very satisfactory working agreement has been reached in the case of operational mathematics. The Electrical Engineering Department teaches an introductory course in electrical transient theory, incidentally introducing its students to Heaviside's Unit Function and the direct operational method. The Mathematics Department follows this with a course in operational mathematics which is in large part a renewed attack on electrical and other transients, this time by the methods of the Laplace transform and the contour integral. This arrangement, of

course, is possible only because the Mathematics Department numbers among its staff several men with a substantial background in and appreciation for the problems of electrical engineering. The situation may be reversed in other institutions, in which case it might well seem reasonable to have advanced students in other engineering fields and in mathematics attend the courses in transient theory offered by the electrical engineering department.

Correlation on the Undergraduate Level

The topics in which correlation is particularly indicated are mentioned in some detail in the papers contributed to this symposium by Professor L. V. Bewley of Lehigh University and Professor G. F. Corcoran of the University of Maryland, who also make specific suggestions as to the handling of these topics. Accordingly, since the papers are available and the authors will lead the discussion that follows, the present paper will be confined in this respect to a brief summary of this material.

Through the Sophomore Year, in most technical institutions of collegiate level, mathematics preparation is the same for all engineering students. It extends through the calculus, though it may end with a brief introduction to differential equations, usually in the last calculus course. These courses must prepare the student for work in physics and mechanics, and the need for correlation with these fields has been pointed out by Dean Justice in his opening remarks. They should also, in the opinion of the writer, include instruction in topics of particular importance to the electrical engineer, such as complex numbers and hyperbolic trigonometry—and stress and illustrate the later use of this material.

Electrical Engineering students generally are required to take at least one mathematics course beyond the calculus. This course is most often Differential Equations, although it may in some cases be entitled "Advanced Mathematics for Electrical Engineers." A number of institutions require both courses.

Differential Equations, if it is the only advanced course taken, and if it is at least the equivalent of one semester in length, should include as well other advanced topics, as is suggested by Professor Bewley. Besides the linear differential equations used in circuit and network theory, such special equations as Bessel's, Legendre's, Poisson's and Laplace's should be discussed, together with the functions which are their solutions. Partial differential equations must be introduced, and in view of its later utility for students of communication, the D'Alembertian wave equation, at least in one dimension, should be studied. Altogether, this constitutes a rather formidable total, admittedly. It is far better if a second course, in "Mathematics for Electrical Engineers," can follow and be used as a catch-all for such additional material as vector analysis, potential theory, and graphical and numerical methods of solution. This course should be closely associated with the senior courses offered by the electrical engineering staff, and since such senior work very properly differs from institution to institution, according to the fields of interest of the professors or the policy of the department, so should the content of the mathematics course. Here there is a splendid opportunity to achieve correlation by close cooperation.

Correlation on the Graduate Level

If there is variance in the senior electrical engineering courses from institution to institution, there is an almost complete lack of uniformity at the graduate level, as may be verified by comparing catalogs or consulting a few of the members attending this conference. The inescapable fact is that any given graduate offering in electrical engineering requires a specific group of associated courses in mathematics. The first step in correlation must be to insure that the necessary mathematics courses are offered, and that they are conducted in such manner as to be most valuable to the engineering students. If advanced machine theory is a specialty of the school, tensor and matrix analysis should be available. Advanced circuit or network courses need accompanying work in complex variable theory, and static field work needs a background in series of complex variables. As has been mentioned, the operational mathematics-transient theory couple might be housed in either department, or might be shared between departments. The same considerations apply to the vector analysis and the partial differential equations needed if students are facing the problems of radiation and other applications of Maxwell's field equations.

In every case, cooperation between departments must be wholehearted, painstaking and detailed, in order to achieve the desirable ends of graduate study. It has been the writer's experience that correlation is most easily achieved at the graduate level, since there minds of similar characteristics meet, and quickly reach understanding. This may not be true in all cases; for example, where the engineering school is but a small part of a large university, but failure to cooperate in this respect is well-nigh inexcusable.

Methods of Achieving Correlation

The Training of the Mathematics Staff is of fundamental importance. It may be assumed that anyone acceptable for the teaching of mathematics at university level is well grounded in that field. If he is to teach his mathematics to embryonic engineers, however, it is just as essential that he be grounded in the fields of engineering as it is for the engineer to be grounded in mathematics. It would be well indeed if the prospective mathematician during his undergraduate days could be exposed to a few courses in physics and technical mechanics, say, or even in engineering, but since such men must now be trained in liberal arts colleges, one is forced to admit a certain lack of practicality in the idea. In passing one wonders whether an undergraduate curriculum in engineering mathematics, in a few of our larger institutions at least, would not be amply justified.

Facing the fact that junior members of the mathematics staff may well be completely innocent of technological matters, it then appears highly desirable that they be encouraged to remedy this lack by taking, formally or informally, course work in at least one engineering field. This practice has been followed for many years, with excellent results, at North Carolina State College. It bore unexpected but welcome fruit during the recent war days, when mathematics professors provided much needed help in the teaching of electrical theory under various war training programs. Quite

recently, a program of graduate study in engineering mathematics has been announced at North Carolina State, and it will be interesting to watch the progress of this experiment.

Interchange of Professors between the departments of mathematics and electrical engineering should produce most salutary results. It would be no waste of time, for example, if each professor of electrical engineering, every three years or so, were to teach a section of differential calculus in the summer session. It would give him a priceless opportunity to demonstrate the improvements in teaching he is prone to recommend to the mathematicians. It would also, one is sure, be of value in freshening up for him fundamental concepts buried too many years deep in his memory. For the mathematician, one does not suggest laboring through the task of teaching direct-current machinery or electronics laboratory, but an occasional fling at teaching alternating-current circuit theory should be stimulating for him and not too harmful for the students.

Adding Mathematicians as Permament Staff Members in a department of electrical engineering, as Professor Corcoran suggests, is a logical extension of professorial interchange. A point of semantics might be argued here: if a mathematician so forswears his first allegiance, is he not, or will he not soon become, an electrical engineer? Or is he an applied mathematician, as engineers are applied physicists? The writer remembers a most stimulating though occasionally overwhelming graduate course in post-newtonian mechanics, taught to him by an excellent mathematician masquerading as a professor of physics.

Liaison Committees between departments are a highly efficient means for working out the details of correlation. In fact, where correlation already is established, one is likely to find such committees functioning, though they may not be listed with the august standing faculty committees on Student Social Affairs and the like. Our liaison committee may actually be nothing more than a few friendly colleagues working together for the common good, but, nevertheless, they work.

In any case, the committee should be small. If the departments themselves are small, the two department heads might constitute the committee. When the departments are so large that the heads must delegate parts of their responsibility, one or, at the most, two representatives from each department should be designated to serve on the committee. These representatives must of course have the confidence of their respective department heads and departmental colleagues, so that their decisions will normally be approved and put into effect with all possible dispatch.

Once the committee has been established, and the other recommended steps in establishing support and cooperation taken, it is time to go into details. Each electrical engineering course should be studied, dissected, and have its mathematical content analyzed by the committee. The same should be done with preparatory and associated mathematics courses. Any need for modification of the latter should then be apparent, and the committee should recommend accordingly. This cannot be done once and for all, but must periodically be redone as new courses are added and old ones change in content, text, or instructor (or all three). It may well be a difficult task, but it should certainly be a rewarding one.

As this work is done, the analyses of mathematics and electrical engineering courses worked out by the committee should be made available to all the members of both departments, and each staff member should conscientiously familiarize himself with the material. Only by so doing will he in his own courses be able to eliminate the deplorable lacunae, the places where he might have made use of the student's powers and did not, or might have taught him something valuable and did not.

This last remark may serve to point the essence and heart of the problem we are discussing. No matter what the methods we devise and try, we will not achieve correlation of our work in these two fields unless and until all the instructors concerned realize its importance—realize it so strongly that they will emerge from behind their departmental barriers and truly join in wholehearted mutual effort. When they do so, the means become unimportant and the achievement inevitable.

The Role of Scientific—and Mathematical—Methods in the Management of Large Scale Enterprise[1]

By RICHARD STEVENS BURINGTON[2]

Bureau of Ordnance, Navy Department[3]

The Importance of Management

It has been said that the important difference between one business and another operating in the same general field is in the people who manage the business. Available to all in a large degree are the facilities for production, standards of technology, capital, a market and a means for capitalizing it. The importance of management is thus clear. The larger and the more diversified the industry, the greater the demands for managerial talent of the highest order—talent which is needed in every phase of the business. Every great enterprise recognizes that the standards required today are higher than ever before. For this reason, any great enterprise must attract and hold in a competitive market managerial talent of the highest type, capable of discharging properly and adequately the manifold responsibilities resting upon them. Administrative talent of the highest type is a best investment for all concerned.

Scientific Methods in Management

As an integral part of the execution, administration, planning, coordination, and operation of such an enterprise, the staffs charged with all or a portion of such activities should have included in their membership men of broad vision and receptive minds, men trained in many fields to act in an advisory capacity to the executives who are charged with making the final decisions. Among this group should be engineers, scientists—and mathematicians—who are capable of making the broadest types of overall evaluations and analyses; men who can penetrate deeply through a mass of sometimes conflicting and irrelevant information to disclose the fundamentals of the problem at hand and to seek and expose the underlying principles involved, men who are capable of using the highest order of scientific methods for providing executives with mature quantitative bases for decisions.

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[1] Address delivered at a meeting of the Mathematical Division of the A.S.E.E., Minneapolis, Minn., June 18, 1947.

[2] The author wishes to express his appreciation for the many critical and extended suggestions made by Captain Phil Niekum, Jr., U.S.N., during the preparation of this paper. He also wishes to acknowledge the critical comments on this subject made by his colleagues Dr. D. C. May, Mathematician, and Mr. Fletcher Byrom, Engineer.

[3] The opinions expressed in this paper are those of the author and are not necessarily those of the Navy Department.

There is a growing bond between the methods used by men in management and those used by scientists. The potential possibilities of this bond are so great that the power of such developments needs to be more fully understood. This is a matter of concern for both executives and educators alike. In particular, those scientists and mathematicians whose interests lie in teaching, or in border field developments, should be especially concerned.

In using the term enterprise or industry I refer to any type of organization, business, utility, production unit, research or development group, be it government or private, be it large or small.

Most of you are well acquainted with the contributions scientists, engineers, mathematicians, physicists, and others have made in the discovery, research, development, production, and realization of all sorts of industrial achievements, the improvement of transport, the widespread introduction of labor saving devices, . . ., and more recently, the great developments of the means for waging war.

While many of the more spectacular achievements have been widely publicized, relatively little is known by the public at large concerning the contributions such professional men can and have made to the planning, execution, coordination, and administration of large scale developments and operations of every conceivable type. Some inkling as to how this has been done in problems relating to the recent war has been published, but the extent to which such methods can be used to greater advantage in all sorts of enterprise is not so well known. These contributions involve the knowledge of many branches of science, and have been and can be made in the best scientific spirit.

An interesting discussion of the possibilities of using scientific methods in statecraft appeared in a recent address by M. H. Stone.[4]

Reasons for Increased Use of Scientific Methods in Management

Some of the many reasons why the managements of large scale enterprises are making much greater use of scientific techniques than ever before are as follows:

(a) The acts and decisions of leaders and executives in a large closely knit industrial organization such as we have in this country tend to have wider, deeper, quicker, and more acute influences upon the courses of events, the flow of production,—upon the industry as well as upon the individual —, than in the days of more localized enterprise. Hence, executives must estimate more carefully the probable consequences of their actions.

(b) The economic situation of this country at present is such that no industry can afford to use costly wasteful processes, cut and tried methods of development, intuition, guesses, hunches, and the like. The growing depletion of the natural resources of this country, the high cost of experimentation in time, personnel and materials, and personnel problems force industries to make much wider use of scientific and analytical methods than has ever been employed in the past. The value "of figuring things out ahead of time," thus, cannot be questioned.

[4] "Science and Statecraft," Marshall H. Stone, *Science*, May 16, 1947, Vol. 105, No. 2733, pp. 507–510.

(c) In order that any industry continue to be healthy and operate in the black, progressively in a competitive market, it is now very necessary that such an industry study and analyze its processes, its modes of production, its modes of marketing, its products, its products improvements, its process developments, its market potentialities, and to evaluate and predict optimum courses of action. For example: any large transportation organization must make continuing analyses of the demand, the cost, and the expected future demand for its services, if the system is to make the best possible use of their revenue and keep their costs within reason. This is particularly true of most transportation systems and utilities, where the margin of profit, if there is any at all, is extremely thin and where rising material and labor costs cannot be off-set by changes in revenue from changes in rates. In these cases, in order to widen this thin margin and in order to produce sufficient revenue, which will permit the industries to make necessary improvements and expansions, it seems obvious that industry must make full use of scientific and analytical methods.

Evaluation and Analysis Groups Needed

Every organization, industry, business, or individual is continually being confronted with new and recurring problems which require serious study and the formulation of new plans and policies. In many organizations this entails carefully made evaluations, predictions, and analyses of operations, plans, and the like, from one or more points of view (usually many points of view). Thus, the engineer, the operating man, the financier, the accountant, the production man, the management man, and the scientist may contribute to such analyses. In almost any large scale undertaking, this means that in the organization provision must be made for an "Evaluation and Analysis Group" whose business it is to undertake a variety of studies along the lines indicated in this paper. This group should include a variety of different types of scientists, physicists, engineers, and other professional talent, including mathematicians, who are capable of making thorough analyses directed in channels indicated by the enterprise, yet in so doing preserve the spirit of scientific research. The head of such a group should operate on a staff level.

Functions of Such a Group

The functions of such a group may include the following items:

(a) Clarification of present and proposed objectives, a statement of needs, a characterization of a criteria for the future. This may involve descriptions and analyses of existing methods, projects, plans, and operations. Such analyses may be broad or detailed. They frequently involve the formulation of theories which must be shown to fit facts and experience. They involve "knowing where we are going before we start."

(b) Clarification of an operational or production process or status. The detection of the existence of problems and questions of which the executives may not be aware.

(c) Analysis of existing methods, plans, projects, development programs, operations, . . . with comparative studies and predictions which indicate the directions in which improvements might be made with existing facilities

and modes of operation. Usually no one point of view is sufficient.

(d) Analyses and evaluations which indicate the need for exploring new fields and for trying entirely different methods, or for developing entirely new materials or systems which would lead both to economy and to improvement in the service or the products of the industry.

(e) Analyses and predictions which indicate the direction in which projects or investigations should be pointed in order to realize the optimum desired results, and in order to realize worth while improvements, both in the relative as well as in the absolute sense.

(f) Analyses and predictions which exhibit the courses of action open together with what is entailed in these courses of action; each course of action being carefully weighed.

(g) Aid in the formulation of policies. This does not mean that the group will formulate or execute the policy, but it may mean that it recommends general policies to the executives who are charged with the burden of making the decisions.

(h) Analyses and predictions which enable the concern to be ready for whatever eventualities may arise.

(i) Aid in the technical direction of the effort on specific projects, tasks, and problems within overall programs.

Prediction

In listing the possible activities of such a group in an enterprise, it is recognized that executive planning involves predictions which are often subject to early test in a competitive market. Accuracy of description and observation, sharpness of analysis, deduction and prediction, and extreme care in the execution of plans are highly important in a competitive world. Accurate estimates of the state of each competitor, the potentialities of markets, all treated in a truly scientific spirit, with up to date estimates of the optimum use of forces, "know how," . . . designed to yield the desired optimum service to the public or the capture of the market, are indicated.

Some management men may feel that much cannot be predicted; thus they then tend to use hunches. However, this need not deter us, for the scientist and mathematician can readily operate and predict—and they do so—with surprisingly good results by interweaving statistical methods and the more determinable dynamical methods. This they can do even though it is not possible to know at any given instant all of the relevant facts upon which events observable at a later date may depend, and even though it is not possible to measure or observe phenomena without the very act of making the observations in some way or other influence the phenomena being observed.

How Mathematical Methods Fit into This Type of Work

The question may arise with some of you as to how mathematics fits into this type of work. The most outstanding feature of the use of mathematics in the role of scientific engineering and management lies in the mode of attack involving a high order of mathematical reasoning.

In tackling many problems which may be faced by such a group in a large scale enterprise, the first big step is often that of determining just what the problems are that need study and to state them in appropriate form. Often the problem as given to the group may not actually be the problem which should be stated and solved.

Some of the work outlined above is, of course, in the nature of routine statistics and routine services which can be done by personnel trained in specific techniques, and some of it is in the nature of general scientific investigation requiring a high order of professional attainment. All of these types of services are, of course, needed to a lesser or greater extent depending on the type of industry. In fact, in most industries much greater use of qualified mathematicians in these fields is an economic necessity. However, there is a much broader use, though not so well known, that can be made and should be made of mature scientists—and mathematician—who have a thorough understanding of the physical properties of nature as well as a deep seated knowledge and sense of the underlying basis of scientific and mathematical things, and an excellent understanding of economics and of men. It is this broader use with which I am concerned here.

When I speak of a mature understanding of the underlying value of mathematics, I refer to that state of development in which a mathematician has a true genuine comprehension of mathematics as an organic whole and as a basis for scientific thinking and acting. It is not so much the formalism, or mechanics of mathematics that is of real importance here as it is the underlying philosophy, structure and methodology of the core of mathematics that are important.

It is an inescapable fact that in order for one to be successful in the field with which this paper deals he must know and have a strong feeling toward physics, engineering, and science in general, and usually, toward the economics of general situations. Without one or the other, one is almost helpless, except for very special detailed items.[5]

When a mathematician who possesses some measure of these characteristics approaches a completely strange physical system or mode of operation, he is better able to classify the available information or to organize it in such a way as to bring out clearly and logically the more important factors and the relations among them; what is known about each of these factors and what needs to be found out about them, all of which leads eventually to a rather clear cut picture of the situation. The resulting picture can then be used as a structure upon which to base further investigation and analysis, showing the possible and desirable directions in which the industry and the individuals should point their efforts.

Remarks Concerning Certain Techniques Useful in this Type of Work

The techniques of a great many branches of science will be found useful in the sort of work discussed here. Of course, the specific fields of most use depend on the particular enterprise involved. However, there are many general statements which might be made concerning the work of an evaluation and analysis group in all such enterprises. I have selected a few such items for consideration here.

Logical Approach. One of the functions of the professional mathematician or scientist who is concerned with the operational analysis or with the evaluation of any kind of system, or process,

[5] "Qualifications for Professional Positions in Applied Mathematics and Related Scientific Fields," Richard S. Burington and Donald C. May, Journal of Engineering Education, April, 1947, Vol. 37, No. 8, pp. 641-652.

consists in the search for a straight forward logical treatment of the components, processes, or factors involved. This treatment should lead to a clear statement of all the pertinent factors; what is known, what is not known, and what can or should be done about them. In other words, out of the mass of information relating to the system being studied must appear an organization of the whole system and related processes which discloses the fundamental underlying elements of the system. Such analyses should clarify whatever is involved and lead to improvements, economies, or knowledge beyond that which was known at the beginning of the study.

Measures of Merit. It is sometimes quite difficult to devise schemes for measuring the worth or merit of a given system or process. Where more than one system is involved, measures of the relative worth or merit must be devised. Usually, one measure of merit is not sufficient, and a whole set of measures of merit may be considered necessary. The ability to set up sound measures of merit for a given system is one requiring considerable insight and often times a broad knowledge of many fields.

Use of Symbols. In carrying out the analyses and evaluations discussed here the expert may prefer, or perhaps may be forced, to use symbols in arriving at his conclusions. The symbols are really used as tools to aid in abstracting the relevant material from the mass of what may be irrelevant or confusing data. However, in preparing a final report for the use of executives, it is usually quite desirable to avoid the use of symbolism. Fortunately, it is possible to formulate the mathematical structure of many problems in ordinary language so that any educated layman can readily understand the treatment and conclusions. This point should be recognized fully by technically trained personnel.

Simplification. When a mathematician tackles an economic or a physical problem, he is, of course, inclined to idealize his problem in such a way as to yield fruitful mathematical results. For example, he may impose linear assumptions or assumptions of symmetry in order to make his mathematical formulation possess a certain esthetic beauty. This is very desirable sometimes, but many times over simplification leads to mathematical results which when interpreted in the physical world lead to quite erroneous conclusions. Thus it often happens that the more difficult and involved assumptions must be employed in order to obtain usable physical results. This is somewhat of a handicap to a purist, or to any one for that matter, but it must be faced. This is one of the reasons why some mathematicians in their research or teaching prefer to work in pure mathematics—their work is then easier, and not so restricted, or so they may feel at times.

Generalization. One of the most powerful methods which research mathematicians use is that of generalization. Generalization can be done in many ways. A generalization may, or may not, lead to useful results. In certain types of generalizations, the situation is made so broad that very few invariant properties are possible. This may be desirable sometimes, but it may also be very undesirable at other times. In applying mathematics to real processes, great care must be exercised not to extend the generalizations involved any further than the underlying (*i.e.* physical, economic, . . .) situation permits or warrants. In many investiga-

tions of systems or processes one of the things which is aimed at is the search for invariants, that is, the search for properties and characteristics of the system under study which will not change under a variety of conditions. Many of these invariants, and all of the fundamental ones, are of basic significance in the underlying (physical, . . .) system. Too great a generalization from the underlying system may lead to a conclusion which states that a certain characteristic is not invariant, whereas, in fact, it is invariant in the underlying system. If the treatment is thorough and adequate the proper degree of generalization for the underlying system will appear when the investigations involved are carried out properly and far enough.

Importance of Attitude. When any one tackles a problem involving the analysis or evaluation of a system or process, he is apt to be handicapped by a sort of unconscious aim to tie down the system to some well defined field of mathematics with which he is acquainted. This is a useful procedure, but the tendency then is to make the treatment of the system under study fit the mathematics, rather than to make the mathematics, which describes the situation, fit the system. This tendency must be guarded against if the analysis or evaluation is to be productive of useful results. Sometimes an unknown, or little known, form of analysis must be developed to fit the system under study. Thus the importance of an open minded attitude and breadth of view is indicated. As discussed elsewhere,[6, 7] this difficulty would be overcome in part if the training of mathematicians, engineers, and scientists were somewhat different from what it is now.

Training. You may ask what branches of mathematics should be taught to train people for work of the sort discussed here. My reply is: training in many fields—and experience.[6, 7] As far as mathematics is concerned, regardless of what you teach, teach for accuracy of thought, expose the underlying structure clearly and simply, placing great emphasis on the significant premises, definitions, and the principal theorems which tie the various relationships together. Teachers of engineering, economics, physics, . . . should strive to bring out the corresponding underlying structure of each particular field, placing emphasis on the relations within this structure, the structure as it actually is, and the structure of the mathematics used.

Such training will contribute materially to the broad understanding, the sharpness, the keenness, the perception so necessary for the successful application of scientific techniques to the technical and management problems discussed in this paper, to problems which sometimes because of the great mass of conflicting, confusing, and irrelevant data are difficult to penetrate to the core of underlying principles.

Research Possibilities. In the development of improved techniques suitable for the use of management executive methods already known in other fields are and will be found valuable. Furthermore, as the use of the mathematical techniques progress many new scientific techniques suitable to this field of management will be developed. In this way new mathematical research

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[6] "Training of Mathematicians," Richard S. Burington, JOURNAL OF ENGINEERING EDUCATION, Dec., 1941, Vol. XXXII, No. 4, pp. 346–352.

[7] "New Frontiers," Richard S. Burington, *Science*, March 30, 1945, Vol. 101, No. 2622, pp. 313–320.

may fit into the field of management in quite a new way.

Conclusion

The time is opportune for management to draw more heavily from contact with the spirit and methods of science—and mathematics. The economic state of industry is forcing and will continue to force this trend. The foundations for a broad and intricate union of science, mathematical science, and management craft are being formed and must be more fully developed. This should be clearly recognized by management, by scientists, by mathematicians, and by educators in their planning and operations.

The Application of Three-Dimensional Dynamic Graphics to the Presentation of Economic Principles*

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It should be mentioned at the outset that no attempt will be made at this time to deliver a discourse on economics. Rather there will be discussed some suggestions on the use of a new tool, or medium of expression, for the exploration, teaching and presentation of economic principles.

It would be difficult to select a subject in which the limitations of the spoken and written word present a greater handicap to a general understanding and grasp than economics. understood meaning. Needless to as "The Dismal Science"—and no wonder! Discussions of economics, whether they be held in the classroom, at the conference table of the "high-powered" business executives or over the average man's dinner table, are ordinarily as coherent as the voices at the Tower of Babel. A multitude of factors are tossed into the verbal free-for-all and, to add to the confusion, rarely do any two of the participants use the same term with a commonly understood meaning. Needless to say, under these circumstances, the discussion is soon in a hopeless mess wherein no two are talking about the same thing or following a center line of thought that leads to a coherent solution.

And it is not surprising that this is so when one considers the vast patterns of activities and far-reaching interrelationships embraced within our economic society.

Clearly, to break through the confusion of words, statistics and charts, some new technique or medium of expression is required. Certainly the gravity of the economic problems confronting us injects a note of compelling urgency to bring the facts down to an understandable level so that all may join forces in pressing towards a solution.

It was, in fact, the urge to overcome this inadequacy of the verbal approach that led directly to the development of what we have called "Three-Dimensional Dynamic Graphics." The particular incident that precipitated action in this direction was a request, a number of years ago, by a financial journal, for an article on foreign exchange.

* Presented at the Conference on Engineering Economy, A.S.E.E. Annual Meeting, Minneapolis, June 18–21, 1947.

After struggling with the preparation of this article, which attempted to show how exchange rates fluctuated in relation to the gold markets, it was finally decided to drop the whole thing; the many factors involved soon surpassed the limitations of writing to keep it all straight. The final outcome, after several years work, was the development of an illustrative series of patterns employing the "Graphic" technique.

The accompanying photographs (Figs. 1 to 6 inclusive) show views of the material developed thus far. It is apparent that the word "graphics" is used here in a far broader sense than is implied in the dictionary definition, "descriptive representation by means of charts, graphs or diagrams." We see here that the Three-Dimensional Dynamic Graphics cogently treat such objects as "Supply and Demand," "Commodity Prices," "Value of Money," and "Distribution of Income" by the integrated use of all types of representations. In the development of this medium of expression the separate fields of physics, chemistry, mechanics and mathematics were tapped. The latest techniques in lighting, color and art were explored. Thus the word "graphics" is used here to imply the combined use of charts, photographs, diagrams, the objects under consideration themselves or replicas of them, and physical, dynamic, analogies of abstract processes.

As we look further into the characteristics of the Graphic technique, we will find that it not only supplements and largely replaces the verbal and conventional graphic approaches, but

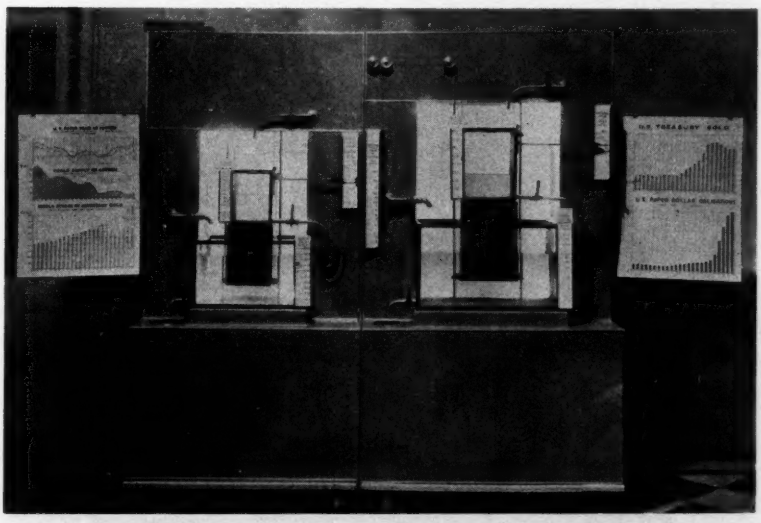

FIG. 1. Three-Dimensional Dynamic Graphics as applied to an analysis of the factors influencing commodity prices. The representation of the supply and demand for commodities, gold and paper money by means of colored liquids and the use of other appropriate analogies makes it possible to portray in concrete form what heretofore largely have been abstract conceptions.

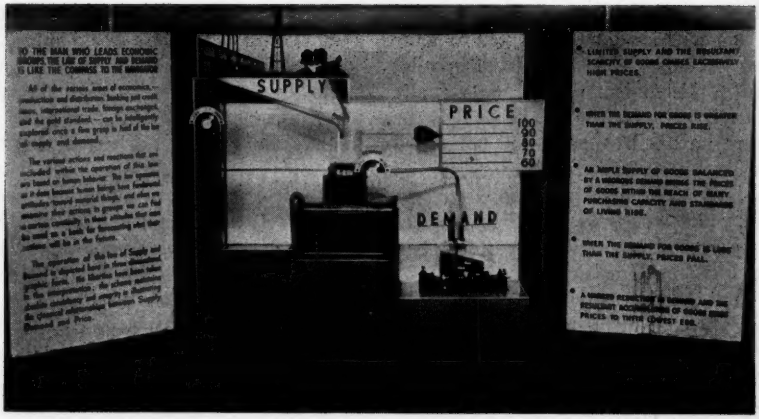

FIG. 2. The operation of "The Law of Supply and Demand" is here depicted in "Graphic" form. No liberties have been taken in the interpretation; absolute consistency and integrity are maintained in cogently illustrating the classical relationships between Supply, Demand and Price.

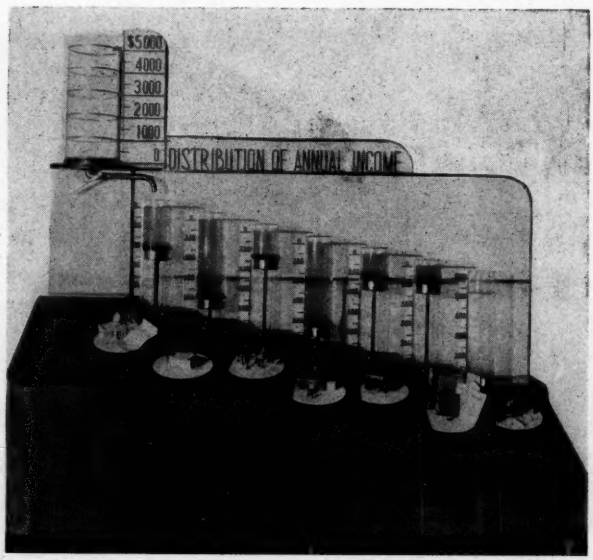

FIG. 3. Replacing the conventional bar chart, this "Graphic" pattern illustrates how a family's annual income distributes itself progressively into the several major classifications of expenditures. By adjusting the various settings and calibrations, a number of different problems dealing with family or National income may be demonstrated.

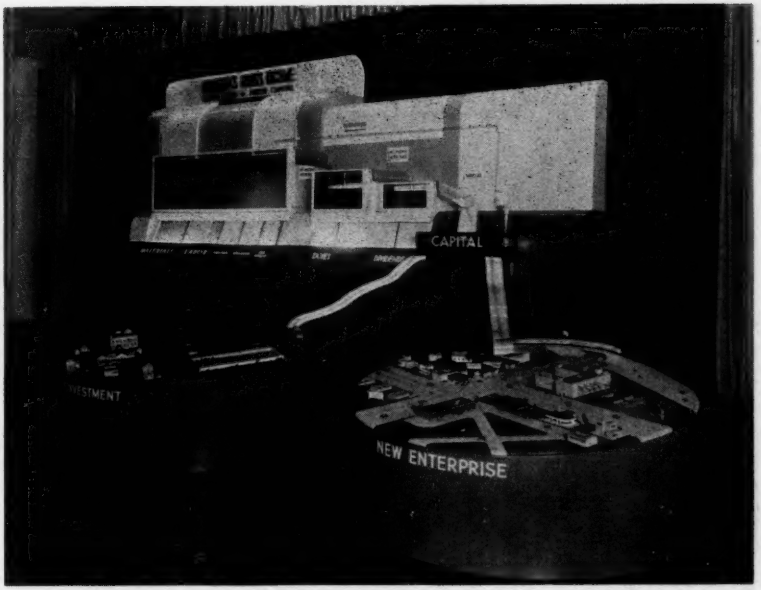

FIG. 4. Here the flow, distribution and conservation of capital in industry are illustrated through the medium of "Three-Dimensional Dynamic Graphics." By applying authentic, factual data to the "graphic" pattern many popular misconceptions regarding the financial aspects of industrial operations may be cleared up.

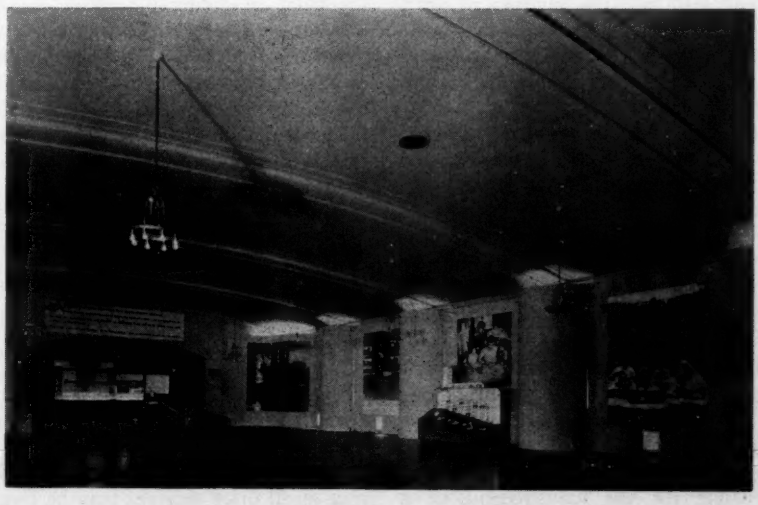

FIG. 5. General view of a comprehensive presentation of economic fundamentals, employing the "Three-Dimensional Dynamic Graphics" which was on exhibit at the Willys-Overland plant in Toledo, Ohio.

FIG. 6. Another view of the presentation at the Willys-Overland plant. Notice the use of the pictorial murals for the purpose of creating atmosphere and adding a down-to-earth sense to the treatment of the subjects.

that it can go further in simultaneously coping with a large number of variables and economic concepts and while doing so, ingests such factors as "quantity," "flow," "direction" and "magnitude."

To better familiarize ourselves with the inherent potentialities of the Graphic technique let us examine, in some detail, one of the units comprising the group thus far developed. For this purpose, let us consider the unit which was designed to assist in the analysis of the factors influencing commodity prices.

As we know, from painful experience, fluctuating prices constitute one of the greatest problems confronting us, from the housewife on up to the average business man or the group responsible for the management of a corporation. Nevertheless, we are in the habit of giving too little thought to what goes on behind the price scene. We think of price simply as the amount of money we must pay in exchange for something we want, and relate price fluctuations to some shadowy thing called "Supply and Demand" and then let it go at that.

Actually, of course, price is not, in itself, a single entity. Instead it is the resulting of a number of more or less independent components. The "graphic" pattern we are about to discuss is an attempt to identify and represent these separate components and thus, in a sense, take the price structure apart and then put it back together again to show how it works.

As we have already intimated, at the root of all price changes may be found

a group of interrelated variables whose combined actions and reactions are commonly referred to as "The Law of Supply and Demand." In fact all of the various areas of economics—production and distribution, banking and credit, taxes, international trade, foreign exchange, the value of money and the gold standard—can be intelligently explored once a firm grasp is had of the law of supply and demand. It seemed logical, then, in developing the Graphic pattern for analyzing commodity prices, to start out with a study of this law.

One of our first steps, accordingly, was to set down, in much the same style used in the elementary science textbooks, a definition of this "law," for example:

> The price of a commodity rises with an increase in demand or a decrease in supply. Conversely the price falls with a decrease in demand or an increase in supply.

Stated in another way:

> As the price of a commodity rises, the demand for it tends to decrease while the supply tends to increase. Conversely as the price falls the demand tends to increase and the supply to decrease.

Thus we had, in verbal form, a statement of the law of supply and demand in its simplest form, without taking into account any consideration of possible fluctuations in the value of the medium of exchange in terms of which the price was stated.

To assist in our thinking we also framed the law in mathematical form, thus:

$$P = \frac{DC}{SC}$$

where:

P = Price
DC = Demand
SC = Supply.

Still another medium for expressing or representing the interrelationships of this law would be by means of a symbolic chart (Chart 1).

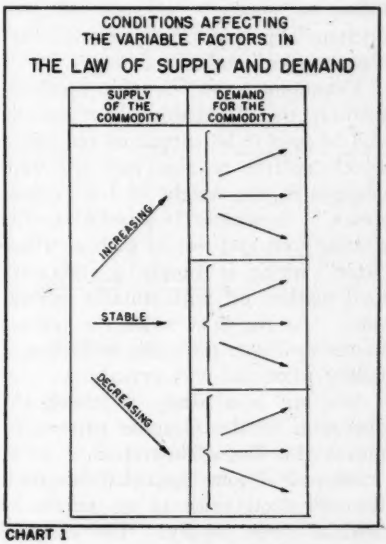

CHART 1

It is interesting to note that the moment we made use of even this simple graphic representation, the "law" takes on new life; new implications arise. The chart suggests, better than do words, that even when stable money is assumed, no less than nine combinations are possible of the variables influencing price.

Let us now see how the law of supply and demand can be portrayed by Three-Dimensional Dynamic Graphics.

To start with, supply and demand are each portrayed by streams of liquid flowing respectively into and out of a

receptacle. Valves are provided so that the rate of flow of the streams may be varied at will. The contents of the receptacle represent the stocks, or inventories, of the commodity offered for sale. It will be noticed that a fortunate harmony exists between the graphic analogies employed and the terms conventionally used in economics; "flow of goods," "streams of production," "pressure," "quantity," "reserve stocks," etc.

Examining the Graphic pattern, further, the "Inventories" receptacle will be seen to be supported on a float which is free to rise and fall with changes in the weight of the "inventories." A pointer is attached to the floating unit and ties in with a "Price Scale" which is simply a stationary card marked off with suitable calibrations. As the float sinks, the pointer moves down on the scale, indicating a falling price and vice-versa.

We are now ready to check the operation of the Graphic pattern by means of a simple illustration.

Suppose it were desired to illustrate the effect on price of an excess of demand over supply. The demand valve would be opened wide while the supply valve would bet set to allow only a small stream to flow. The difference in the rates of flow of the two streams would gradually drain off the "inventories." The decreasing weight of liquid in the inventories receptacle would cause the float to rise, symbolizing a rise in price. All of the reactions portrayed here in Graphic form would be in full accord with economic reality.

The opposite case, an excess of supply over demand, or any number of variations, could also be illustrated and the portrayal would jibe with economic fact as well as with the foregoing verbal, mathematical and chart expressions of economic behavior.

Notice, however, that the Graphic pattern is capable of reaching beyond the limitations of the verbal, mathematical or conventional charts representations. The Graphic technique is able to ingest and cope with factors not readily handled by the other mediums. Only in the Graphic pattern are the concepts of "rate of flow" and "volume," for example, injected in a concrete way along with the implications they introduce. While the verbal, mathematical and chart expressions all tell us that an excess of demand over supply will cause a rise in price, they do not show us, through the three-dimensional medium, the actual dynamic flow and the graphic treatment, how the relative rates of flow cause the inventories to be depleted with a resultant rise in price. Nor can they portray the various graduations that can be illustrated with the Graphic pattern.

Still another important advantage is that the Graphics arrangement lends itself to calibration under appropriate conditions. For example, in the original development of this Graphic treatment of commodity prices, actual statistics on cotton, monetary stocks of gold in the World and in the United States, and Government paper dollar obligations were used. The resultant pattern, which gave an analysis of cotton prices, was checked by Alston H. Garside, then Economist of the New York Cotton Exchange, who endorsed the integrity and accuracy of the portrayal. When the calibrations and setting of the Graphic pattern were adjusted in accordance with the statistics applying to successive years, a price curve was traced which was in remarkably close agreement with historical fact.

Having digressed for the moment, let us return to a consideration of the price structure and let us continue to translate the various concepts into the Graphic pattern.

We have just discussed the relationships that exist between supply, demand and price, assuming, all the while, a stable medium of exchange. Suppose we now introduce the complicating fact that the value of the medium of exchange may vary. The economic phenomena involving the additional variables may, of course, be described verbally, although we will not take the time here to set down the necessary phraseology.

We can indicate the general nature of these effects in another mathematical shorthand statement, thus:

$$P = \frac{DC}{SC} \times \frac{1}{VM}$$

where the new term

VM = Value of Money.

Or we can restor to an elaboration of the chart previously used (Chart 2).

It immediately becomes apparent that the introduction of the additional variable, the value of money, has complicated our problem considerably. Instead of the original nine possible combinations of the factors affecting price, we now have 27. If we go a step further and introduce individually the separate supply demand factors influencing the value of the medium of exchange we would have 81 combinations.

To go even further along this line, if instead of the general term, "medium of exchange," we inject the concepts of gold and paper money and, following that, introduce the separate supply demand factors surrounding

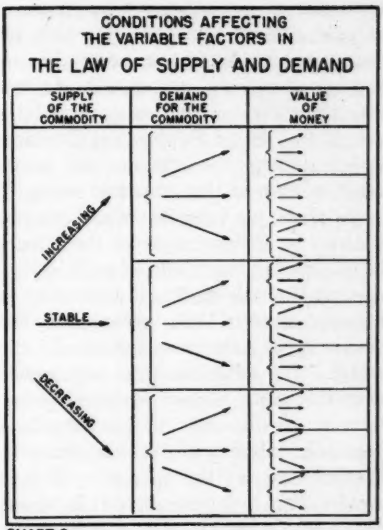

CHART 2

them, we would find that we could chart as many as 6,561 different combinations of the variables.

Needless to say, by this time we would have far surpassed the ability of the verbal, mathematical or chart expressions to convey to our minds, much less anyone else's an intelligible impression of the workings of the price structure. Thus, it is evident that as the number of variables increases, the full merit of the Three-Dimensional Dynamic Graphic technique becomes apparent.

Let us now see how the Graphic pattern portrays price fluctuations caused by changes in the value of the medium of exchange. The float supporting the "commodity inventories" is seen to rest in a stock of liquid which represents, in this particular study, World stocks of monetary gold; *i.e.*, the medium of exchange. Additions to, and withdrawals from this stock, that is, the supply and demand

for gold, are represented by streams of gold colored liquid flowing into or out of the tank. To express this in another way, we are merely saying that the value of gold is governed by the same Law of Supply and Demand which exerts its influence in every other corner of the economic scene.

To check the integrity of the graphic analogy in its portrayal of the effects of changes in the value of gold, let us assume that the stocks of gold were to increase greatly, due perhaps to the discovery of vast new deposits of the metal. We all know from experience that the more of any commodity we have at our disposal, the less valuable it becomes. Hence, in the case assumed, the increase in the quantity of gold would cause a depreciation in its value. What would be the effect of this on the price of the commodity, and how would this manifest itself in the Graphic pattern?

It will be realized that the rise in level within the gold tank will cause the float carrying the commodity receptacle to rise. The price pointer, being attached to the float, will also rise, reflecting the fact that gold has dropped in value and, therefore, more of it must be given in exchange for a unit of the commodity.

Obviously many other examples can be illustrated, but rather than to take the time to do this, we shall indicate briefly how the factors surrounding the value of paper money are introduced and interpreted by the Graphic pattern.

Although, thus far, we have used the term "price of the commodity," we have, strictly speaking, been dealing with its "gold value." In every day affairs, however, we do not give much thought to gold values. We ordinarily think of the price of things in terms of the paper money of our country. To portray the concepts of these two separate "price tags," we have two price scales in the Graphic pattern. The first scale, which is the one we have been dealing with up to now, indicates the "gold value" of the commodity, as for example, so many grains of gold per pound of cotton, or bushel of wheat. A second price scale, placed alongside the first, indicates the paper money price, equivalent to the gold value existing at the moment. This price would be quoted, for example, in terms of cents per pound of cotton, or dollars per bushel of wheat.

The numerical relation existing between the gold value and the paper money price will depend, of course, upon the prevailing "value," or "gold content," of the dollar. This consideration, however, introduces a host of new factors which, in their influence upon the gold value of money, also affect the money price of commodity. The factors influencing the value of the dollar are portrayed in the larger of the two cabinets of the Graphic pattern. We find that the mechanical arrangement is already familiar, for the simple reason that the Law of Supply and Demand is again being portrayed; changes in the value of money being subject to the same basic laws of human behavior. The interrelationship of value existing between gold and the dollar, that is, the "gold content of the dollar," is indicated on a scale which gives the "Price of Gold" in terms of dollars per fine ounce of gold.

This relationship, of course, is ordinarily fixed, or pegged, by law and in the Graphic pattern, a "Price Peg" makes it possible to peg "the dollar price of gold" at any desired figure. Some rather interesting reactions are seen to occur, in spite of the presence of the price peg, when such factors as

the "Total Government Dollar Obligations" are allowed to get remarkably out of line with the other factors. For example, should the dollar obligations be increased out of normal proportion to the "Treasury Gold Holdings," it will be noticed, on the Graphic pattern, that "Paper Dollar Prices" begin to creep upward. This happens even though the "Gold Value of the Commodity" remains unchanged.

If the experiment is carried still further, the stresses caused by the forces at work strive to manifest themselves in a rise in the "Price of Gold"; that is, a decrease in the "Value," or "Gold Content," of the dollar. But the price peg prevents this change in value from being apparent on the scale.

If the forces become too great, however, the price pointer gives way and the entire system goes through a series of violent fluctuations. Equilibrium is finally restored but with a new value relationship existing between gold and paper money. It will be found, when the system settles down, that the "Price of Gold" is at a higher level than before and that "Commodity Prices," in terms of paper money, have risen in exact arithmetical proportion. Meanwhile, assuming no other changes have been made, the "Gold Value of the Commodity" has remained unchanged.

This is only one of the many problems concerning price that can be illustrated by means of this Graphic pattern. Time does not permit further demonstration.

Briefly, in review, this Graphic pattern makes it possible to show that price is not, in itself, a single entity. Rather it is the resultant of a number of independent variables. Using the Law of Supply and Demand as our basis, we can trace through the price structure to determine in what ways the separate factors effect price. Although there are far more variables than could comfortably be handled through the medium of words, mathematics or charts, the Graphic pattern makes it possible to deal with them either individually or simultaneously. Thus we are able to progress, step by step, in an orderly analysis of the price picture.

The Graphic pattern just discussed is but one of several that have been developed to date. A brief description of these other patterns will serve to indicate the adaptability of the Graphic technique in presenting other economic fundamentals.

An adaptation of the pattern just described goes a bit further in adding a sense of realism and life to the portrayal of the Law of Supply and Demand. Whereas in the first example, the various actions symbolizing economic phenomena are manually controlled, the demonstration is rendered more vivid by providing means for automatically varying the streams of supply and demand in accordance with changes in price. Thus, the various actions and reaction that constitute the "law" are enacted in a dynamic manner; supply and demand automatically interacting with each other and price. When let to itself, this Graphic pattern always seeks equilibrium and comes to rest with price at a "normal" or "average" level, and with supply and demand flowing copiously. Any external influence tends to upset the balance, but the directions of the forces at work are always such as to reestablish the equilibrium.

The Three-Dimensional Dynamic Graphic technique has also been applied to a portrayal of the distribution of family income. This pattern replaces the conventional bar chart in

dynamically illustrating how a family's income distributes itself progressively into several major classifications of expenditures. The sequence in which the liquid flows and apportions itself represents the priority in which each class of expenditure normally exerts its claim upon the income. By adjusting the volume of the separate containers and by using other sets of calibrated scales, or even other groups of model replicas, it is possible to experiment with and illustrate a wide variety of problems dealings with the distribution of family, industrial or National income.

Still another pattern cogently shows the flow and regeneration of capital within industry operating under our system of free enterprise. "Industry's Gross Income," stemming from sales and fresh capital, is portrayed by means of a stream of liquid which flows into a tank and furnishes the "Operating Capital" required to meet the cost of materials, labor, management, depreciation, rent and interest, all of which are represented by streams draining from the bottom of the tank. After "Operating Expenses" have been met, the "Net Income Before Taxes" runs off through an overflow to a tank from which "Taxes" are withdrawn. The remainder overflows to still another tank where it is divided between "Dividends" and "Surplus." The pattern emphasizes the importance of surplus as a source from which capital may be drawn for investment in new enterprises or for reinvestment in going concerns.

In conclusion the point is again stressed that the development of these Graphic patterns does not represent an attempt to expound any economic theories or doctrines, either new or old. All that has been undertaken has been the development of a means for exploring and interpreting, in a concrete way, what heretofore largely have been abstract conceptions. Throughout the development work every effort was made to maintain absolute integrity and consistency with economic reality. No original data or statistics were derived; those used were taken from standard and authentic sources.

It is also pointed out that none of the patterns is presented as a finished product. All are original, experimental models and obviously much refinement is possible. However, it is hoped that the work done thus far will be accepted as a suggestion of an approach for presenting some of the basic economic principles underlying our system of free enterprise.

Educational Problems of Graduate Student Theses Based on Sponsored Research*

By JOHN W. M. BUNKER

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If a graduate student bases his thesis upon his own research, which is part of a sponsored program, does the sponsorship itself create a situation likely to be unfavorable to his education?

This is a question which is pertinent because of the unusually large amount of government-sponsored research in pure and applied science, in this post-war period, in universities which are crowded with graduate students seeking research subjects for theses. Moreover, since the question has been raised in respect to government-sponsored research, how about institutional research under industrial sponsorship?

These are questions which seem destined to create considerable commotion in academic circles, and the degree of agitation occasioned by their consideration varies immensely with restrictive definition of the premises.

Money, as a medium of exchange, is paid out only in return for something received or expected, and money paid into a university is no exception. When funds are made available for university research, it is important that the recipient institution stipulate that they are accepted for expenditure under stated conditions which are compatible with university ideals and objectives. These in the main comprise the advancement of knowledge and its dissemination without special privilege or favor, with reservation of right to decide what, when and where to publish. Under such conditions a contract colloquially may be described as "without strings." Research under a contract "without strings" is appropriate for graduate student participation and presents no educational problems on account of the contract.

If military foresight or industrial self-interest requires restrictions on publication of results, it is usually better that a graduate student keep clear in so far as thesis work goes. However, in every administrative formula part of the formula should be a provision for its violation when there is good reason therefor.

On the other hand, contracts for development of particular devices do merit scrutiny, lest thesis research thereunder become too much directed training and too little constructive contribution.

A contract tendered by a business concern is likely to be for a particular service of immediate interest to that concern, although Industry is coming to realize that its future growth will thrive in proportion to the quality and capacities of its future employees, now in school. Directors and heads of business are less likely to quibble over

* Presented at the Conference on Graduate Studies at Minneapolis, June 19, 1947.

patent rights, publication, etc., than are the lesser men in their organizations. The universities will have less trouble in arranging sponsored research if dealings are with the top men in the sponsoring agency.

There is the matter of preference among competing governmental bureaus for work in a given area. The less experienced bureaus are more prone to attempt to dominate in institutional contracts. The better organized and more experienced agencies are more aware of the importance of essential basic fundamental exploration of backgrounds than are the more quick-on-the-trigger, speedy-action boys, and are more satisfactory to deal with.

In a statement of policy relating to governmental contracts for research, one of our engineering institutions points out that "As an American institution devoted to education and the advancement of knowledge in the field of technology, this institution has always felt a special responsibility to render public service, especially to any branch of local, state or federal government. As a private institution, chartered to perform specific functions and operating largely on funds given for its corporate purposes, the governing body of this institution must retain proper control of the operations carried on by or in the name of that institution. In order to perform its best service to the government, this institution feels it must be free to operate without restrictions which in its judgment would reduce its effectiveness. Imposition of governmental controls or methods would weaken or destroy the very factors which differentiate educational institutions from governmental establishments. Hence, if the government has good reason to desire a private institution to undertake a project, there is equally good reason why the government should not interject into the institution's operations more than a minimum of governmental procedures and controls, otherwise the government would weaken the institution's principal asset, and the job had better be kept out of the institution and set up under full governmental control in a governmental establishment."

In a planned research program involving development or design, any portion thereof which requires that a solution to a problem must be achieved by a definite date in order that the project may be completed on a fixed time schedule seems inappropriate for student research. The fact of a deadline date is likely to be too much in the mind of a research supervisor who then is likely to be impatient with the amateur investigator's meandering, and constantly to tell him where lies the trail from which he has strayed. To be sure, it is a part of educational technique to teach the wanderer how to find his own way back to the path, else on his first exploration without a guide the tenderfoot gets lost. This takes patience and an amount of time that is unpredictable.

To regard with disapprobation a research project for a student solely because it is in applied science has no logical justification. The problems of professional practice are pragmatical, but their solution may require the utmost of basic science. Too often, the term "pure science" is used to bolster the wavering self-respect of the intellectually undisciplined dilettante, who usually is the only one to look down his nose at the "practical" fellow. There is of course a danger that applied science may become gadgeteering

or hardware engineering, but to the climber, the necessity of guarding against the abyss on either side adds zest to the ascent of the ridge.

A student enrolled for thesis on contract research recently complained that he found his initiative curbed by conditions of his work on a project which had as its objective the perfection of a device. It would be easy to blame the contract or its objective for this dissatisfaction; more judicial would be an inquiry into the technique of his research supervisor. Was the student's part of this larger project wisely chosen? If it was the student's choice, was he wisely counselled when it was approved? Not all thesis topics in pre-war days were wisely selected. What of the other students on the same project who did not express dissatisfaction? Was this because they were less mentally alert, or did their thesis subjects give them a better break, or was their guide more skillful? It does not do to judge from isolated evidence.

The feeling has been expressed that a stipulated budget on a contract research makes a supervisor less tolerant of inefficient efforts of the beginner, and results in the latter being "told" what to do too often for his own good. If there be in a contract that which is absent from institutional appropriations which encourages keeping the budget balanced, perhaps this is not an unmitigated evil. But as long as the supervisor recognizes his primary obligation as that of educator, it would seem that the more careful his bookkeeping the better for all concerned.

Waste cannot be condoned by the excuse of academic freedom. On the other hand penny pinching may well reduce the full measure of educational service. In Utopia there will be no stint of funds for untrammeled research; in America research costs money and an awareness of its value is not a demerit. It seems difficult to maintain an assertion that consciousness of a limit to funds expendable should of itself pose an educational problem for participants in a research. The more one examines the experiences of teachers and students in regard to participation in research, the cost of which has a definitely detectable sponsor, the more it appears that if there be any difference between the educational value of such sponsored research and other institutional research (the funds for which have been derived from a less directly traceable source), this difference exists for one of two reasons: either the institutional authorities which accepted the contract did not exercise wise choice in accepting restrictions therein, or the research supervisors have compromised their educational ideals. There need be nothing in contract research per se to create any educational problem.

On the other side of the ledger one can find definite assets and advantages for the student participant. Although intelligence will always outrank equipment for promoting research achievement, brains plus equipment offer a combination that is greater than the sum of its parts. Time spent by mortal is gone from him forever; equipment saves time, and equipment is an expected accessory of a sponsored project. A student participant in a research project which has ample shop, production, and testing facilities, may have at his ultimate disposal material resources far beyond those which the contracting institution could otherwise provide.

As one concrete example, the thesis subject of John Doe was the theoretical

solution of a problem in tracking, from an air-borne source, an object in flight. A highly theoretical solution was prepared by him and its mathematical support was convincing. This would in any day be regarded as commendable student thesis achievement. Because he had contributed to one phase of an extensive contract research, there were made available to him the services of a machinist suitably equipped to turn out precision instruments, and he was able to have the design translated into fabricated equipment. In one of the project's planes he tested his equipment on suitable targets, and the plot of results justified the predictions of the theory. This is a solution in which hypothesis has been scientifically established and actually tested. The results are valuable to the art involved, and to the confidence of the investigator on his first important test in scientific engineering research.

Another type of advantage from participation in a well supported program of research is illustrated by the field of servo-mechanisms in which a problem usually involves the consideration of an entire system. Although research on integral parts of the system or upon solution of theoretical matters leading to design of a single component may often be entirely suitable as a challenge to the creative scientific imagination, the added value which comes from fitting such solutions into a balanced dynamic system is something extra. If a theoretical solution is translated into instrumentation, is this not the normal course of events in useful engineering practice?

Still a third advantage may accrue to the student when his thesis is based upon an integral part which is selected because of its pertinence to a whole solution. This is the accessory value which comes from interchange of experiences and views with fellow workers all of whom have a common bond of interest in that they are working toward a common end. The sense of belonging is a valuable asset to any human being. To belong to a group all working toward a common useful end contributes to morale, and is a spur to added effort. Each member of a real team endeavors to carry out his own assignments and not to let the other fellow down. This is good training for effective citizenship as well as for participation in research team work.

It is a healthful thing for an educational institution to inventory from time to time both its research commitments and its research educational methods. It is even of value to imagine evils of pressures in contract research whether or not they exist, for if they do, then corrective measures will be applied, and if they do not, still the process of self-examination may disclose that which has been overlooked. It is equally sound practice to take stock of educational practices in general, and to formulate the things that should not be done so that each of us can be reminded against slipping into ways of doing things that are not the best ways for our students.

In student thesis research, much depends upon the motivation of the thesis supervisor. He must never forget that he is first of all, and in spite of any considerations whatsoever, an educator charged with educational responsibility. This responsibility is to bring out in students those skills and capacities which, if effectively applied, will result in creative professional performance. The objective of the thesis supervisor is not to produce volumes of publishable material. That is a by-product of his main job which is to produce the

producers of the future. The attainment of thesis results worthy of publication may be properly set as the evidence that this educational job has been properly done, but the evidence must not be confused with the goal itself, nor be substituted for it. To train a skillful manipulator to carry out one's own ideas is to have produced an apprentice but not a master.

To develop the master, we must lead the student more and tell him less. How to do this is a perpetual educational problem. It is a problem which seems less acute in the case of a doctoral thesis than it is in the more abbreviated master's research; it appears to an engineer to be less acute in the fields of abstract science than in those of applied science, perhaps partly because the grass is always greener in the other fellow's yard.

In the professional world into which our graduates will enter, there are relatively few opportunities for a life career in an ivory tower. The needs of a changing social order in this technological age are specific and acute. Results are demanded, and it may be more and more difficult to secure the support necessary for creative fact finding research which is the necessary foundation for the applications so obviously needed.

We are very likely in the midst of a change in our universities. Perhaps the comfortable isolation and independence which we like to call academic freedom are changing. Perhaps we have to yield something in order to exist. Let the yielding be apparent rather than real, if come it must. Integrity cannot be compromised, expediency is to be shunned, but a higher degree of academic respect for research in applied science may be practical as well as deserved. Concrete results will always more readily persuade financial backers; that is a result of human nature.

To quote from the Manual of Graduate Study published by this Society in 1945, "The preparation, execution, and defense of a thesis is an extremely useful part of professional education. It is normally required that the Master's thesis demonstrate the ability to analyze a problem clearly and either to carry on a research assignment with *reasonable guidance* (italics are editorial) by the thesis advisor, or to develop a design incorporating novel features. . . . The requirement for the Doctor's dissertation is invariably independent research culminating in an original contribution to engineering."

This or an equivalent guide should be always in mind when appraising a project for its suitability for graduate student participation. If the problem is one that challenges the student's capacity to draw upon the facts accumulated in his previous and current educational experience; if it challenges his ingenuity to devise its solution; if it be one in which his participation gives him pride, that is a suitable thesis research problem. That is the only sort of problem that can with fairness to him be approved. How the expenses are met, whether by direct or indirect contribution, seems to be beside the point.

The conclusion, therefore, seems justified that there need be no educational problem involved in graduate student participation in research solely because it is part of a sponsored contract; there always have been and always will be many educational problems in the direction of graduate student research in general.

Some Problems of Military and Naval Training Programs*

By EVERETT D. HOWE

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The recent report of the President's Advisory Commission on Universal Training indicates that the peace time military and naval services will aggregate 1,535,200 men, and that something like 30,000 new regular and reserve officers must be supplied each year. The present service academies are limited in physical size and can produce only about 1,300 officers each year. The Army and Navy have, therefore, turned to the civilian colleges for the training of the bulk of the officers needed. The plan is to subsidize the education of those who may elect the Army or Navy as careers, permitting them to follow regular civilian college curricula, but requiring them to include appropriate military or naval training courses in their programs each term. Commissions in the regular Army or Navy are awarded to these men when they graduate from college. Students who do not select the Army or Navy for careers may take the same training without subsidy and may be awarded Reserve commissions upon graduation. Thus, the ROTC and NROTC programs of the present day differ from those of prewar days in that they must provide training at least equivalent to that characteristic of the service academies. If this equivalence is not achieved, the graduates of civilian colleges who become career officers may be seriously handicapped in competing with academy graduates.

The plans for ROTC and NROTC training in colleges require that each trainee must undertake one course in the training program each term, three hours per week in the first two years and five hours per week in the last two years. In land-grant institutions, in which military or naval training must be provided for all able-bodied male undergraduates, there is little or no problem of time or units at the freshman and sophomore levels. At the junior and senior levels in these colleges, and at all levels in non-land-grant colleges, there is difficulty in finding time and units available in certain curricula, notably those in engineering. This shortage of available space has become more acute since the war due to revisions in the engineering curricula which require the students to include more of the social-humanistic studies in their programs than was formerly the case. For example, the prewar curricula in engineering at the University of California, Berkeley, included from 110 to 114 units of required scientific and professional courses as compared with the total of 136 units needed for graduation. Deducting from the residue of 22 to 26

* Presented at annual meeting of the A.S.E.E., Minneapolis, June 18, 1947.

units, the eight units reserved for lower division military training, there was a net amount of 14 to 18 units which the student could use as he wished—for social-humanistic studies, for technical studies, for military or naval training, or to a limited extent for physical training. In contrast, the present engineering curricula at the University of California aggregate from 131 to 136 units for graduation and include: provision for between 111 and 114 units of scientific and professional courses, 12 units of social-humanistic courses, and 8 units of lower division military training. Thus, as matters now stand at the University of California, the student enrolled in upper division ROTC or NROTC must present 16 units of excess credit for graduation, gaining these units by heavier-than-normal programs during the regular terms or through attendance at more than the regular eight terms required by his curriculum. This state of affairs has led to criticism by the Naval and Military officers on the Berkeley campus who feel that the 16 units of military or naval training should be included in the 136 units required for graduation. It is believed that this same problem exists in varying degrees on other college campuses and is the source of many discussions relating to curricula and similar matters.

If officer candidates are expected to follow the normal civilian curricula and are to do this without extra units of work, the 16 units involved must be traded for 16 units in other subjects. Most present-day engineering faculties are unwilling to approve the deletion of any of the social-humanistic studies and do not consider the military and naval courses equivalent to the junior and senior required courses which would be displaced. Even though some of the military and naval courses include technical material, the prerequisites enforced and teaching methods used are such as to preclude treatment of the subject matter in the scientific and analytical fashion characteristic of junior and senior courses in engineering, science and mathematics.

Although matters of curricula form the major content of the two other papers in this symposium, it is believed appropriate to emphasize here that career officers in the Army and Navy are not primarily technical specialists. If the philosophy basic to the curricula used at Annapolis and West Point is correct, further consideration should be given to ROTC and NROTC curricula parallel thereto and leading to degrees other than the usual engineering degrees.

The Departments of Military and Naval Science and Tactics differ from other departments on civilian college campuses in several important respects. In other departments, the faculty member is chosen by college authorities after careful investigations of his competency in the subject field and consideration of the candidate's desire and ability to teach. After appointment, such faculty members are expected to increase in knowledge and ability through research and teaching over extended periods of time. In contrast, the professors of military and naval science and tactics are selected by the Army and Navy, approved by the college authorities without much investigation, and assigned to teaching duty for brief periods of time. The brevity of his stay prevents the instructor in these fields from developing his teaching methods very far or from undertaking research.

A second noteworthy difference be-

tween the departments of military and naval science and tactics and other departments is the complete lack of graduate and faculty research. Those officers who are sent to the colleges for post-graduate work are generally assigned to studies in other scientific or professional schools of the institution. While this condition may be explainable in terms of the brief tenure accorded the officer-instructors, it introduces the question as to whether or not the Army and Navy are receiving maximum value from their connections with civilian institutions. Subjects such as ballistics and damage control are seldom studied in civilian departments, but may be appropriate fields for graduate research in the military and naval departments respectively. The co-operation of faculty members in the mathematics, science and engineering departments could conceivably advance knowledge in such fields to an appreciable degree.

In summary, it is fair to state that college administrators believe the ROTC and NROTC programs to have a place in civilian institutions, and that these activities furnish the colleges with an opportunity to contribute directly to national security. It is suggested that changes in policy with regard to curricula, selection and tenure of officer-instructors, and graduate instruction could result in an increased return to the Army and Navy for their investment.

Notes on the Use of the Log-Log Slide Rule in Connection with Trigonometric Functions

By R. T. BROWN

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The well known cosine law may be revised to avoid the necessity of adding and subtracting squares, as indicated below:

$$\cos A = \frac{b^2+c^2-a^2}{2bc}.$$

The numerator lacks only 1 term, $2bc$, of being the difference of two squares, namely, $(b+c)^2-a^2$. This expression yields: $(b+c+a)(b+c-a)$. Adding and subtracting $2bc$ we have $\frac{(b+c)^2-a^2-2bc}{2bc}$ or $\frac{(b+c+a)(b+c-a)-2bc}{2bc}$ which is equivalent to $\frac{(b+c+a)(b+c+a-2a)}{2bc}-1$. The reason for using the form in the second parentheses $(b+c+a-2a)$ is that where once the three sides have been added the second term may be obtained readily by subtracting twice the side opposite. When solved by slide rule (or by logs) the quotient falls between 1 and 2 and the 1.0 is dropped to obtain the cosine. When the angle is greater than 90° the quotient is less than 1.0 and the result is therefore minus. In either case three digits are available as cosine, with the third digit uncertain. However, the angles so obtained by slide rule solution are about as close as by the use of the half-angle method for sine or cosine. Example: Sides a, b, $c=25$, 38, 33 respectively. $a+b+c=96$; $96-2a=46$, $-2b=20$, $-2c=30$. $\text{Cos } A=\frac{96\times46}{2\times38\times33}-1=0.761$, $\cos B=\frac{96\times20}{2\times25\times33}-1$ $=0.164$, $\cos C=\frac{96\times30}{2\times25\times38}=0.515$.

When using sine $1/2A=\frac{\sqrt{(s-b)(s-c)}}{bc}$ and $\cos\frac{1}{2}A=\sqrt{\frac{s(s-a)}{bc}}$ with the slide rule it is desirable to use the former for angles between 0° and 120° and to use the latter for angles between 120° and 180° so that the half angle will fall in the area in which the angles are subdivided to 10 minutes or less. Between 60° and 120° either formula falls in that area. However, for angles less than 32° the sine formula and above 148° the cosine formula give results in the area where the subdivisions are 5 minutes or less.

When seeking the cosines of small angles or sines of large angles the following expressions may be used for greater precision:

$$\cos A = 1 - \frac{\sin^2 A}{2} \quad \text{and} \quad \sin A = 1 - \frac{\cos^2 A}{2}.$$

Examples: $\cos 3° 20' = 1 - \frac{\sin^2 3° 20'}{2} = 1 - 0.00169 = 0.99831;$

$$\sin 88° 20' = 1 - \frac{\cos^2 88° 20'}{2} = 1 - \frac{0.000845}{2} = 0.999577+.$$

Occasionally, particularly in dealing with grades in mechanics problems, it is desirable to determine the sine of a small angle when the tangent is given. Since the ST scale is actually a sine scale, although used for both sin and tan, the one cannot be determined from the scale directly. However, since $\sin A = \frac{\tan A}{\sec A} = \frac{\tan A}{\sqrt{1+\tan^2 A}} = \sqrt{\frac{\tan^2 A}{1+\tan^2 A}}$ it is a simple matter to set the hairline on the given tan on D scale and divide the square on A by 1+the square on B and read the sine or D at the C index. Example: $\tan A = 0.0425$; $\sin A = ?$; $\sqrt{\frac{0.0425^2}{1+0.0425^2}} = 0.0421 = \sin A$. This method, is of course, not limited to small angles as $\sin(\tan^{-1} 0.325) = \sqrt{\frac{0.325^2}{1+0.325^2}} = 0.316$. Similarly sine may be converted to tan by $\tan A = \frac{\sin A}{\cos A} = \frac{\sin A}{\sqrt{1-\sin^2 A}}$. Example: $\sin A = 0.5575$; $\tan A = \sqrt{\frac{0.5575^2}{1-0.5575^2}} = \sqrt{\frac{0.31}{0.69}} = 0.671+$ (0.6716− by tables).

To determine more precisely the angle when a given sine or cosine is near 1.0 and the angle sought is consequently in the area of no subdivisions use may be made of the relationship $\sin^2+\cos^2=1$; thus: $\sin A = 0.982$, $A = ?$, $\cos A = \sqrt{1^2-\sin^2} = \sqrt{(1+0.982)(1-0.982)} = \sqrt{1.982 \times 0.018} = 0.1888$, $A = 79° 07'$.

These examples illustrate and emphasize the fact that an accurate slide rule is really an instrument of precision when used properly. We are not forced to use the ST scale and use approximate values for tangents nor to guess at the angles between 80° and 90°.

Minutes of the Meetings of the Executive Board and the General Council

Meetings of the Executive Board and the General Council of the A.S.E.E. were held in the Willard Hotel, Washington, D. C., November 10–11, 1947. Those in attendance were: C. E. MacQuigg, President, C. J. Freund, F. M. Dawson, B. J. Robertson, S. S. Steinberg, J. S. Thompson, A. B. Bronwell, Nell McKenry, W. T. Alexander substituting for W. C. White, H. H. Armsby, H. W. Barlow, G. F. Bateman, E. S. Burdell, T. C. Hanson, W. L. Hughes, H. K. Justice, E. L. Lehman substituting for A. W. Turner, W. B. Plank, J. E. Thornton, J. H. Zant. The following items on the agenda were considered by the Executive Board and recommendations made which were presented to the General Council:

1. Report of the Secretary; (2) budget for 1947–48; (3) report on the scheduling of conference programs for the anual convention; (4) subjects and speakers for the general sessions of the annual convention; (5) A.S.E.E. as an agency for the exchange of teachers; (6) policy which A.S.E.E. should adopt in securing members from junior colleges and technical institutes; and (7) relations with other engineering societies. Action on these matters and others considered by the General Council are:

1. The Secretary, A. B. Bronwell, reported progress in the work of that office; that the transfer of office facilities from Pittsburgh to Evanston has been completed; that the Society's funds are deposited in an Evanston bank which has always maintained a high degree of liquidity and has remained solvent through depression years; that a membership drive is under way with a committee of approximately 500; that Miss McKenry has transferred to Evanston to assist him; and that the work is progressing satisfactorily.

2. The following revised budget for 1947–48 was adopted:

RECEIPTS:

Current dues	$32,000.00
Back dues	1,000.00
Advertising	6,500.00
Sale of publications	1,000.00
Interest on government bonds	350.00
Total estimated receipts	$40,850.00

DISBURSEMENTS:

Annual meeting	$ 1,000.00	
JOURNAL and *Proceedings*	16,000.00	
Sec. salary, Oct. 1 to July 1	3,750.00	
Clerical assistance	5,000.00	
Sec. honorarium, F. L. Bishop	1,065.00	
Conferences	800.00	
Postage, tel. and tel.	2,500.00	
Sundry printing	1,500.00	
Officers' travel	600.00	
Secretary's office travel	500.00	
Dues: Amer. Council on Education	100.00	
Contribution to ECPD	500.00	
ECAC	2,200.00	
ECRC	3,600.00	
Emergencies	500.00	
Chem. Eng. Summer School	300.00	
Moving Secretariat	3,721.00	$43,636.00
Estimated deficit		$ 2,786.00

3. The following recommendations were made on contributions and appropriations:

a. In 1945–46 the A.S.E.E. budget included $300 for the Measurement and Guidance Project which was not paid since no invoice was received. The Secretary was instructed to write to the Project asking if financial support of the A.S.E.E., present and past, was needed, and assuring them of our earnest desire to cooperate.

b. Motion passed that a contribution of $25.00 be made to the Wickenden Award for Excellence in Speaking and Writing in lieu of flowers at the funeral.

c. Motion passed that the retirement allowance of F. L. Bishop for the present fiscal year ($480.00) be sent to his family and that this would terminate the retirement allowance.

d. Motion passed that, in the future, the various publications of the Divisions of the A.S.E.E. be placed on a self-sustaining basis. An appropriation of $89 was approved for the Civil Engineering Division for publications this year only.

e. Motion passed that President MacQuigg ascertain if additional funds for the Lamme award can be obtained so that this fund may be put on a self-sustaining basis.

f. Motion passed that the cost of publishing the Report on Salaries in Engineering Schools in THE JOURNAL OF ENGINEERING EDUCATION be charged to the fund appropriated for this purpose.

4. The Secretary was instructed to secure an estimate on the cost of publishing the JOURNAL from other publishing companies.

5. The following schedule for the June, 1948, convention was approved:

Monday, June 14—
Morning, registration
Afternoon, conferences
Evening, Council dinner meeting

Tuesday, June 15—
Morning, general session
Afternoon, conferences
Evening, family get-together

Wednesday, June 16—
Morning, general session, ECRC
Afternoon, conferences
Evening, conferences

Thursday, June 17—
Morning, general session, ECAC
Afternoon, conferences
Evening, annual dinner

Friday, June 18—
Morning, general session
Noon—adjournment

6. The question of whether or not the Society should serve as an agency for the employment of teachers through advertisements of positions and teachers available in the JOURNAL was discussed by the Executive Board. The Board expressed approval of the plan but took no formal action.

7. It was recommended that the A.S.E.E. adopt a policy of securing members from faculties of junior colleges and technical institutes in order to further its objective of improving engineering education.

8. An informal report from the President's Commission of Higher Education was presented by A. B. Bonds, Assistant Executive Secretary. A resume of statistical services provided by the U. S. Office of Education was reported by R. C. Story, who outlined controlled sampling methods which will be used to gather statistical data on teaching loads, salaries, etc., in universities and colleges.

9. The Committee on Secondary Schools recommended that a new committee be formed which will be responsible to the Engineering College Administrative Council and that this committee include representatives of the divisions of physics, chemistry and mathematics, as well as other divisions of the Society, and of representatives from secondary schools. Committee members are to have staggered three-year appointments. Report adopted upon motion.

10. President MacQuigg reported that a conference on the improvement of textbooks was held in Schenectady on August 12. Objections to existing textbooks are: (1) textbooks often present the personal view of the author and the way he desires to teach material which may not be the best method of presentation; (2) many textbooks are merely a rehash of other texts; (3) textbooks often teach obsolete practices and fail to keep abreast of new developments. The Schenectady conference recommended that the matter be taken up by the A.S.E.E. At the General Council meeting it was pointed out that (1) economic forces compel authors to write the best possible textbooks in order to assure good sales; (2) textbook relationships are matters of concern primarily between the author and the publisher since they are both interested in maximum adoptions; (3) technical conferences in rapidly developing technological fields can serve to improve the technical background of authors, thereby improving textbooks.

11. The Canons of Ethics for Engineers of ECPD were approved by motion.

12. Resolutions expressing the gratitude of the Society for the many valuable contributions and inspiring leadership of F. L. Bishop and W. E. Wickenden were adopted. Copies of these will be sent to the families and published in the JOURNAL.

13. J. E. Thornton, representative of the English Division, presented a report recommending council sponsorship of the English Division's proposal for improvement in the training of

teachers of English; motion passed. The English Division has been sponsoring a project for the improvement of teacher training for a number of years.

14. The Executive Board recommended the appointment of a committee to investigate inter-society relationships. The General Council requested the Secretary to make this survey.

15. Professors Clyde Park and G. W. Stewart were voted to life membership.

16. H. S. Rogers will investigate the desirability of the A.S.E.E. becoming affiliated with the Engineers' Joint Council.

17. The improvement of instruction in extension schools and smaller colleges was discussed. This was considered to be a local problem to be treated by local Sections of the Society or by other groups.

18. 71 new members were elected to membership, making a total of 232 new members for the year.

An Appreciation of Dr. Frederic L. Bishop

Dr. Frederic L. Bishop was elected Secretary of the Society for the Promotion of Engineering Education at the twenty-second Annual Meeting and served the Society continuously and most devotedly from the summer of 1914 to the fall of 1947, during which period its membership multiplied four times and its strength and influence grew in even larger proportions. He guided its operations through two world wars, through two educational surveys and through a reorganization which changed the name to the American Society for Engineering Education. He brought to the office of the Secretary a broad knowledge of science and engineering, a wide acquaintance among professional and industrial leaders, and a consecrated interest in engineering education. These were expanded during his term of office by his experience as Head of the Department of Physics and Dean of the Schools of Engineering and Mines at the University of Pittsburgh, and through his consulting engineering practice in the field of glass production, as well as by his service within the Society itself.

His intimate knowledge of education, industry and public administration, and his practical experience in physics and engineering made his counsel of special value in the work and deliberations of the Society. His devotion to the Society, his loyalty to professional ideals, and his keen sense of responsibility pervaded his thinking and work. His modesty, kindly spirit and friendly manner endeared him to all with whom he was associated.

We are deeply grieved at his passing and shall greatly miss him in our tasks and from our companionship. We are proud to have had him as one of our great constructive leaders over so long a period of years and to acknowledge his valuable contributions to our service.

William E. Wickenden

Only now and then does a leader appear who can see as far as his professional colleagues would like to see, who can identify the crux of a problem they have tried to identify, and visualize and depict in vivid language a situation they have tried to understand. President William E. Wickenden was such a leader.

As a colleague, he was superb. His clear mind, high ideals, and gift of expression made it both rewarding and a pleasure to work with him. And his patience and warm, friendly manner endeared him to all who had the privilege of his association.

As Director of the investigation of engineering education sponsored by the S.P.E.E. in the 1920's he acquired a background in this field and a grasp of its problems that have been unmatched. The Report of this study stands as a fitting monument to his great work. His contributions to the revision of the constitution of the Society in 1946 were invaluable. Under his leadership as President, the influence of the Society added stature to the engineering profession.

And as President of one of the leading engineering schools of the country he found a setting in which his talents as a great educator and administrator had full play. His constructive service of 18 years to Case Institute of Technology closed with his retirement in the summer of 1947.

But in his mind this was not to end his service to engineering education and to his country. That his plans for a further active crusade in behalf of the engineering profession should have been cut short by his untimely death is an irreparable loss to the profession and to the Society, and especially to the hundreds of his colleagues and friends—the engineering teachers of the country.

Therefore, BE IT RESOLVED that we the members of The American Society for Engineering Education hereby formally express our sorrow in the death of William E. Wickenden and our gratitude for the services he so richly gave.

The Lamme Medal

The November 1946 number of the JOURNAL contained a brief statement concerning the bases upon which the Lamme Medal is awarded through action of the twelve members of the Society who compose its committee for this purpose. It pointed out that these bases stem directly from the provisions of Mr. Lamme's will that the medal is "to be given yearly to a chosen technical teacher for accomplishment in technical teaching or actual advancement in the art of technical training."

Actually, over the years, perhaps half of the medalists have been men whose outstanding achievement has been as engineering teachers, but in the remaining cases, excellence in teaching has been suplemented or even surpassed by unusual contributions to the methods and content of engineering education. In general, the Lamme medalists have been men who were already widely recognized as leaders in engineering education and whose work and influence seem likely to stand the test of time.

The members of the Society may be interested in the actual procedure of the committee in making its selection. Early in January, the Chairman requests each member of the Committee to submit three candidates for inclusion, together with those submitted by other members of the Society, in a preliminary list for the current year. The Committee members are then asked to select from this preliminary list five candidates in order of preference. From these selections weighted in accordance with the preference expressed by the committee members, the chairman prepares another list containing those men who have received a sufficiently large number of votes to make it possible that one of them might be selected as the medalist. In recent years, this list has usually included six to eight names. With it, the chairman submits biographical sketches of each of the men in closely comparable form. By one or two further ballots, this list is reduced to two names, and the committee members are then asked to vote upon them in order to determine the medalist for the year.

The committee is most anxious to have members of the Society submit nominations for the award and requests that there be included with them appraisals of the individual's achievement in engineering education and significant factual information not readily available in "Who's Who in America" or "Who's Who in Engineering." To be considered in the current year, nominations should be sent before February 16th to the committee chairman, Donald S. Bridgman, 195 Broadway, New York 7, N. Y.

The George Westinghouse Award

The George Westinghouse Award is an annual award established in 1946 by the Westinghouse Educational Foundation to recognize and encourage outstanding achievement in the teaching of students of engineering. The Award consists of $1,000, together with an engraved certificate. The recipient is selected by a nine-man committee appointed by the President of the Society. The Award for 1948 will be presented at the banquet of the annual convention in Austin, Texas, June 17, 1948.

The recipient of the Award must have made a clearly discernible contribution to the art and science of teaching and shall have distinguished himself in several of the following ways:

(a) Success as a teacher must be established both as to competence in subject matter and ability to inspire students to high achievement as demonstrated by the careers of former students.

(b) Improvement of the tools of, and conditions for, teaching. Evidence of such achievement may consist of subject matter (textbooks, etc.); courses or curricula; teaching, testing, and guidance techniques; laboratory or other teaching equipment; and other similar activities.

(c) Improvement of teaching through various activities, including the development of teachers in a department, contributions to the better preparation of teachers, promotion of cooperation with other types of educational institutions, or with industry, and the coordination of fields of subject matter.

(d) Improvement of teaching through the effect of personal inspiration and leadership.

While there is no specific age limit, special consideration will be given to younger persons who have demonstrated evidence of continuing activity as superior teachers and who are in the process of contributing to the advancement of engineering education.

Nominations may be made by any person, organization, or group and are to be submitted before March 15, 1948, to the chairman of the Committee on Award, Professor H. E. Wessman, Dept. of Civil Engineering, New York University, New York 53, New York. Nominations must be made on forms available from either the chairman of the Committee or from the Secretary of the Society. Nominations should be accompanied by significant evidence supporting all statements and claims.

Sections and Branches

The twelfth annual meeting of the **Allegheny Section** was held at Pennsylvania State College, October 10–11. Dean H. P. Hammond gave the address of welcome and C. E. MacQuigg, President of the A.S.E.E. was the speaker at the dinner meeting. The following papers were presented: M. A. Edwards, "The Characteristics of Curricula Designed to Train Engineering Students for Research"; E. A. Walker, "The Organization of a Research Laboratory"; and R. A. Hussey, "The Business Organization of a Research Laboratory." Newly elected officers for the Allegheny Section include: W. A. Koehler, chairman; R. C. Gorham, vice chairman; D. T. Worrell, secretary.

The twenty-eighth annual meeting of the **Kansas-Nebraska Section** of the American Society for Engineering Education was held at Manhattan, Kansas, October 17 and 18, 1947. The meeting opened with a dinner at the Kansas State College Cafeteria with the President of the Section, L. B. Smith of the University of Nebraska, presiding.

F. L. Brown of the University of Kansas made the award for the Deans' Prize Paper. The first prize was awarded to E. Bruce Meier, Instructor in Engineering Drawing at the University of Nebraska. The title of his paper was "Can Speed Be Taught." The second prize went to M. R. Alder, instructor in Civil Engineering at the University of Nebraska, for his paper, "A Proposed Revision in the Present Course of Study for Civil Engineering Students Together With the Need for Such a Revision." The Deans' Prize Paper Contest is open to instructors under 32 years of age who are members of school faculties within the Section.

R. M. Green, Dean of the University of Nebraska, was the principal speaker. His topic was "A Rebel Yells."

The Saturday morning, October 18, program consisted of a Symposium on "The Selection and Training of Engineering Teachers." The following men participated in the Symposium: Harry L. Daasch, University of Kansas; O. J. Ferguson, Dean, University of Nebraska; and Linn Helander, Kansas State College.

A new constitution was adopted by the Section and the following officers were elected for the coming year:

President: Harry L. Daasch, University of Kansas.
Vice President: J. S. Blackman, University of Nebraska.
Secretary-Treasurer: Reed F. Morse, Kansas State College.
Council Representative: L. E. Conrad, Kansas State College.

College Notes

Dean S. S. Steinberg of the **University of Maryland College of Engineering,** and President of the Engineering College Administrative Council of ASEE, has been appointed chairman of a committee on accrediting of Latin American engineering colleges, it was announced by President H. T. Heald of the Illinois Institute of Technology who is Chairman of the Committe on Engineering Schools of the Enginers Council for Professional Development, the national engineering accrediting agency. Dean Steinberg recently made a survey of engineering schools in Central and South America for the U. S. Department of State. The objective of the new committee will be to promote closer relations between the engineering colleges of the Western Hemisphere by facilitating the transfer of engineering credits earned at Latin American institutions and giving recognition to their engineering degrees.

James B. Conant, President of **Harvard University,** was elected as Chairman of the Board of the newly-formed Educational Testing Service, an organization which has been created to merge the testing activities of three leading non-profit agencies, the American Council on Education, the College Entrance Examination Board and the Carnegie Foundation for the Advancement of Teaching. Henry Chauncey, director of the College Entrance Examination Board, was elected President of ETS.

The purpose of the new organization is to develop more effective examinations from the first grade to graduate school, better intelligence and aptitude tests, and to conduct intensive research in new testing methods.

In addition to the income from its testing services, the ETS will have capital assets of approximately $1,200,000. Carnegie Corporation of New York is contributing $750,000 of this total, and the balance is being provided from the assets of the College Entrance Examination Board and the American Council on Education.

A center for scientific aids to learning to study methods of collecting, organizing, and communicating knowledge will be established at the **Massachusetts Institute of Technology** under a grant of $100,000 from the Carnegie Corporation of New York, Dr. Karl T. Compton, President of the Institute, announced today. The new center is conceived as a national and international resource in its field and will concern itself with research and experimentation on aspects of printing, documentary reproduction, visual education, sound recording, and mechanical selection systems. It will also serve as a center for training technicians, librarians, and others in allied fields in the theories and practices of scientific aids to learning.

Dr. Oleg Yadoff, a former professor at the Sorbonne in Paris, has been appointed Research Associate in Civil Engineering at **Columbia University.**

Dr. Hans F. Mayer, former director of the important Berlin laboratory of the Siemens & Halske electrical firm, has been named a professor of electrical engineering at **Cornell University.**

New Members

ADAMS, HENRY P., Director of Technical Training, Okla. A. & M. College, Stillwater, Okla. Edward R. Stapley, DeWitt Hunt.

AIKELE, CARL M., Instructor in Chem. Engrg., Mich. College of M. & T., Houghton, Mich. M. W. Bredekamp, G. Machwart.

ALTPETER, ROGER J., Associate Professor of Chemical Engrg., Univ. of Wisconsin, Madison, Wis. R. A. Ragatz, C. A. Hougen.

AMELOTTI, EMIL, Assistant Professor of Mathematics, Villanova College, Villanova, Pa. J. S. Morehouse, M. B. Potter.

ANDEEN, JOHN W., Assistant Professor of Mechanical Engrg., Univ. of Minnesota, Minneapolis, Minn. A. O. Lee, M. H. LaJoy.

ANDERSON, JAMES H., Instructor in Mechanical Engrg., Univ. of Minnesota, Minneapolis, Minn. F. Holtby, B. A. Crowder.

ANDERSON, RICHARD D., Associate Professor and Head of Dept. Engineering Shops, South Dakota State College, Brookings, S. D. E. E. Johnson and W. H. Gamble.

ANDERSON, SVEN A., Associate Professor of Economics, Rensselaer Polytechnic Institute, Troy, N. Y. E. H. Van Winkle, H. O. Sharp.

ARMENTO, WILLIAM J., Instructor in Civil Engrg., College of the City of New York, N. Y. C. W. Cunningham, W. Allan.

ARNOLD, JOHN EDWARD, Asst. Prof. of Mechanical Engrg., Mass. Inst. of Tech., Cambridge, Mass. J. A. Hrones, A. Sloane.

BAKER, HAROLD M., Asst. Prof. of Mechanical Engrg., Univ. of Pittsburgh, Pittsburgh, Pa. T. G. Beckwick, N. L. Buck.

BANNON, ROBERT E., Asst. Prof. of Mechanical Engrg., Newark College of Engineering, Newark, N. J. F. D. Carvin, H. E. Walter.

BARKAN, HERBERT, Instructor in Mathematics, Newark College of Engineering, Newark, N. J. Carl Konove, Pompey Mainardi.

BARTEL, HERBERT H., Instructor in Civil Engrg., Southern Methodist Univ., Dallas, Texas. I. W. Santee, C. H. Shumaker.

BARZELAY, MARTIN E., Associate Professor of Aero. Engrg., Syracuse Univ., Syracuse, N. Y. L. R. Parkinson, J. A. King.

BASOCO, M. A., Professor and Chairman, Dept. of Mathematics, Univ. of Nebraska, Lincoln, Nebr. E. J. Marma, T. T. Aakhus.

BAXTER, ALBERT N., Lecturer in Mechanical Engrg., Univ. of So. Calif., Los Angeles, Calif. S. F. Duncan, D. M. Wilson.

BECKER, JOHN C., Lecturer in Mechanical Engrg., Univ. of So. Calif., Los Angeles, Calif. E. K. Springer, T. T. Eyre.

BERNARD, BROTHER ALFRED, Professor of Mathematics, Manhattan College, New York City, N. Y. R. T. Weil, Bro. A. Joseph.

BERTSCH, CARL V., Asst. Professor of Physics, Newark College of Engineering, Newark, N. J. R. O. Hoffman, F. D. Carvin.

BESIO, CHARLES A., Asst. Professor of Mechanical Engrg., Southern Methodist Univ., Dallas, Texas. C. H. Shumaker, I. W. Santee.

BOEHNE, EUGENE W., Associate Professor of Electrical Engrg., Mass. Inst. of Tech., Cambridge, Mass. H. L. Hazen, C. L. Dawes.

BOUDREAUX, FELIX J., Asst. Professor of Electrical Engrg., Southwestern La. Inst., Lafayette, La. H. R. Mason, G. G. Hughes.

BREESE, EDWARD Y., Instructor in Econ. and Social Sci., Georgia School of Technology, Atlanta, Ga. W. J. Proctor, H. E. Dennison.

BRETSCHER, ERWIN R., Asst. Professor of Civil Engrg., Univ. of Illinois, Urbana, Ill. W. A. Oliver, W. C. Huntington.

BREWSTER, MAURICE R., Professor of Econ. and Social Sci., Georgia School of Technology, Atlanta, Ga. H. E. Dennison, W. J. Proctor.

BROOKES, JOHN F., Professor Civil Engrg., Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

BROWN, JAMES S., Asst. Professor of Mechanical Engrg., Tennessee Poly. Inst., Cookeville, Tenn. D. W. Mattson, J. M. Henderson.

BROWN, LABRY, Associate Professor of Civil Engrg., Tennessee Poly. Inst., Cookeville, Tenn. J. M. Henderson, S. S. Steinberg.

BUCHBINDER, HAROLD G., Instructor in Mechanical Engrg., Northeastern Univ., Boston, Mass. W. C. White, W. T. Alexander.

BURGESS, JOHN, C., Instructor in Engrg., Brown University, Providence, R. I. L. T. Bohl, F. O. Rose.

BURROUGHS, HOWARD A., Associate Professor of Electrical Engrg., Michigan College of M. & T., Houghton, Mich. V. O. York, G. W. Swenson.

BUTKUS, JOHN, Instructor in Civil Engrg., Ill. Inst. of Tech., Chicago, Ill. E. I. Fiesenheiser, P. C. Huntly.

CAGE, JOHN M., Professor of Electrical Engrg., Purdue Univ., Lafayette, Ind. L. E. Beck, D. D. Ewing.

CAMBRE, ROLAND J., Associate Professor of Mechanical Engrg., Southwestern La. Inst., Lafayette, La. H. R. Mason, G. G. Hughes.

CASE, HARRY W., Associate Professor of Engrg. and Psychology, Univ. of Calif., Los Angeles, Calif. C. M. Duke, W. L. Orr.

CHAPEL, RAYMOND E., Instructor in Mechanical Engrg., Okla. A. & M. College, Stillwater, Okla. R. M. Aldrich, R. R. Irwin.

CHAPMAN, ALAN J., Instructor in Mechanical Engrg., Rice Institute, Houston, Texas. John Doggett, L. B. Ryon.

CHRISTMAN, WEBSTER M., JR., Asst. Professor of Engrg. Drawing, Univ. of Wisconsin, Milwaukee Ext. Div., Milwaukee, Wis. H. R. Puckett, L. Hillis.

CLAIBORNE, HARRY C., Instructor in Chemical Engrg., Univ. of Tennessee, Knoxville, Tenn. H. J. Garber, F. S. Riordan.

CLARK, EDITH, Professor of Electrical Engrg., Univ. of Texas, Austin, Texas. C. E. Rowe, W. R. Woolrich.

CLOTHIER, JOHN B., JR., Asst. Professor of Electrical Engrg., Villanova College, Villanova, Pa. J. S. Morehouse, E. L. Haenisch.

COLLIER, HERMAN E., Instructor in Mechanical Engrg., Tennessee Poly. Inst., Cookeville, Tenn. D. W. Mattson, J. M. Henderson.

COLLINS, HERBERT, Instructor in Social Studies, North Carolina State College, Raleigh, N. C. A. M. Fountain, H. F. Dade.

COMFORT, EDWIN G. H., Asst. Professor of Mathematics, Ill. Inst. of Tech., Chicago, Ill. S. F. Bibb, P. Huntly.

COMP, LAVERNE A., Professor of Aeronautical Engrg., Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

CONVERSE, HELEN C., Asst. Librarian, Virginia Poly. Inst., Blacksburg, Va. E. B. Morris, J. W. Whittemore.

COSENS, KENNETH W., Asst. Professor of Civil Engrg., Univ. of Texas, Austin, Texas. P. M. Ferguson, V. S. Doughtie.

COTTON, G. ROBERT, President, Kansas Vocational School, Topeka, Kansas. C. E. MacQuigg, W. D. Turnbull.

CRAUN, HORACE D., Associate Professor of Electrical Engrg., Tenn. Poly. Inst., Cookeville, Tenn. H. M. Crothers, J. M. Henderson.

CREECH, MERL D., Associate Professor of Mechanics, Univ. of Okla., Norman, Okla. R. V. James, F. S. Roop.

DAGUE, BYRON S., Asst. Professor of Mechanics, Thayer School of Civil Engrg., Hanover, N. H. W. P. Kimball, E. S. Brown.

DAILEY, LAURENCE T., Asst. Professor of Chemical Engrg., Southwestern La. Inst., Lafayette, La. H. R. Mason, G. G. Hughes.

DAKAN, ARTHUR W., Lecturer in Engrg., Univ. of So. Calif., Los Angeles, Calif. R. E. Vivian, K. C. Reynolds.

DAMM, JOHN A., Asst. Dean, Stevens Inst. of Technology, Hoboken, N. J. K. J. Moser, G. P. Rettig.

DAVIDSON, DARRYL E., Instructor in Mechanical Engrg., Univ. of Nebraska, Lincoln, Nebr. A. A. Luebs, N. H. Barnard.

DAVIDSON, WOODROW W., Associate Professor of Engrg., North Texas Agricultural College, Arlington, Texas. R. W. Binder, E. H. Flath.

DAVILA, ARTURO B., Asst. Professor of Mechanical Engrg., Univ. of Puerto Rico, Mayaguez, P. R. C. C. Mota, A. B. Bronwell.

DAVIS, DONALD W., Asst. Professor of Electrical Engrg., Villanova College, Villanova, Pa. J. S. Morehouse, W. A. Slavin.

DAVIS, LOUIS E., Asst. Professor of Mechanical Engrg., Univ. of California, Berkeley, Calif. R. C. Grasso, E. P. DeGarmo.

DECKER, JOHN L., Asst. Professor, North Texas Agricultural College, Arlington, Texas. R. W. Binder, E. H. Flath.

DEERE, DON, Associate Professor of Civil Engrg., Univ. of Puerto Rico, Mayaguez, P. R. C.C. Mota, A. B. Bronwell.

DICKINSON, CHARLES E., Asst. Professor of Landscape Architecture, Lincoln Univ., Jefferson City, Mo. W. Jackson, D. S. Eppelsheimer.

DILLON, FRANCIS J., Instructor in Engrg., Univ. of Bridgeport, Bridgeport, Conn. L. D. Jones, C. E. MacQuigg.

DODSON, CHARLES R., Associate Professor of Petroleum Engrg., Univ. of So. Calif., Los Angeles, Calif. R. E. Vivian, A. Hansen.

DOGGETT, BYRON C., Instructor in Engrg. Drawing, A. & M. College of Texas, College Station, Texas. F. E. Walling, C. H. Ransdell.

DOWNEY, GLENN L., Instructor in Engrg. Mechanics, Univ. of Nebraska, Lincoln, Nebr. E. J. Marmo, T. T. Aakhus.

DUDEK, EDWARD F., Instructor in Engrg. Mechanics, Univ. of Nebraska, Lincoln, Nebr. E. J. Marma, T. T. Aakhus.

EATON, JAMES R., Associate Professor of Electrical Engrg., Purdue Univ., Lafayette, Ind. D. T. Campbell, C. R. Nichols.

ECKEL, WILLIAM J., Instructor in Electrical Engrg., Thayer School of Engrg., Hanover, N. H. J. A. Wood, Jr., J. J. Ermenc.

EDWARDS, JAMES L., Instructor in Mechanical Engrg., Clemson A. & M. College, Clemson, S. C. A. D. Lewis, S. M. Watson, Jr.

ERBACH, WALTER C., Instructor in Engrg. Mechanics, Univ. of Nebraska, Lincoln, Nebr. E. J. Marmo, T. T. Aakhus.

ERDELYI, EDWARD, Special Lecturer in Electrical Engrg., Newark College of Engrg., Newark, N. J. R. L. Witham, A. A. Nims.

FARRELL, MARTIN B., Instructor in Engrg. and Mathematics, Long Beach City College, Long Beach, Calif. F. A. Dow, L. T. Black.

FARRISEE, WILLIAM J., Dean of Men, Clarkson College, Posdam, N. Y. J. H. Davis, W. H. Allison.

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400 new members, 12–1–47

Undergraduate Engineering Students, Enrollment as of November 1, 1947

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1946–47		
	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W
Aeronautical	1880	846	11	2555	1499	9	1806	1132	26	1402	878	17	147	24	—	25	10	—	217	123	3	8032	4512	66	986	524	11
Agricultural	481	197	1	659	398	—	442	282	—	258	188	2	11	10	—	13	4	—	—	—	—	1864	1079	3	118	65	—
Architectural	1705	867	31	2305	1561	32	1292	901	33	707	519	28	87	57	4	19	15	4	40	35	—	6155	3955	132	262	174	15
Ceramic	192	149	2	371	239	1	257	174	4	177	121	4	—	—	—	14	10	—	—	—	—	1011	693	11	97	42	2
Chemical	5946	1757	16	7001	3889	42	5329	3318	32	3984	2363	29	312	171	4	30	15	1	925	419	7	23527	11932	131	2526	1184	34
Civil	6324	2566	7	9746	6061	30	7120	4796	21	4714	3321	16	205	116	—	94	48	1	1328	626	3	29531	17534	78	2564	1461	28
Electrical	9753	4121	18	19412	12735	31	12767	8986	27	7210	4930	23	397	231	1	163	90	—	2477	1395	13	52179	32488	113	3642	1913	16
Eng. Physics	353	133	3	793	455	11	619	377	9	368	186	5	96	—	—	7	3	—	51	25	1	2287	1179	29	176	75	3
General	4615	2683	41	3283	2163	16	1257	940	1	531	500	2	4	4	1	13	13	—	655	463	2	10358	6766	63	390	120	4
Industrial	1202	483	—	2491	1497	5	2502	1571	3	1791	1055	2	61	47	—	49	32	—	350	238	5	8446	4923	15	958	477	4
Mechanical	10033	4239	19	17400	11194	41	13126	9564	40	9771	6502	36	482	319	1	114	34	—	2382	1359	14	53308	33211	151	5826	3057	16
Metallurgical	644	291	1	1099	632	1	849	571	2	707	490	6	8	8	1	4	1	—	125	62	3	3436	2055	14	520	242	2
Mining	538	242	—	806	463	—	577	331	—	423	255	1	6	—	—	35	5	—	—	—	—	2385	1296	1	229	115	—
Naval Arch. & Marine	47	5	—	91	10	—	50	3	—	74	4	1	3	—	—	1	—	—	—	—	—	266	22	1	81	19	—
Petroleum	1173	612	2	1595	906	1	1158	856	1	610	437	—	22	19	—	8	4	—	—	—	—	4566	2834	4	422	299	1
Unclassified	12603	5293	62	3497	2664	9	840	678	7	492	392	13	84	72	—	223	76	1	8103	3748	387	25842	12923	479	337	121	2
Totals	57489	24484	214	73104	46366	229	49991	34480	206	33219	22141	185	1925	1078	12	812	360	7	16653	8493	438	233193	137402	1291	19134	9888	138
Enrollment in Extension Centers*	1924	634	1	748	418	—	47	38	—	6	2	—	—	—	—	31	16	—	675	420	—	3431	1528	1	—	—	—
Grand Total	59413	25118	215	73852	46784	229	50038	34518	206	33225	22143	185	1925	1078	12	843	376	7	17328	8913	438	236624	138930	1292	19134	9888	138

* Extension center enrollment figures are given in the supplementary table for those schools which reported their extension enrollment separately.

Akron	204	130	—	207	168	—	51	45	2	39	34	—	62	59	—	—	—	—	—	—	—	563	436	2	36	34	—

Grand Total	59413	25118	215	73852	46784	229	50038	34518	206	33225	22143	185	1925	1078	12	843	370	7	17528	8913	458	230824	136956	1292	79161	7888	466

* Extension center enrollment figures are given in the supplementary table for those schools which reported their extension enrollment separately.

Akron	204	130	—	207	168	—	51	45	2	39	34	—	62	59	—	—	—	—	—	—	—	563	436	2	36	34	—
Ala. Poly	447	201	1	602	496	2	519	463	2	307	272	1	—	—	—	18	8	—	—	—	—	1893	1440	6	209	—	5
Ala. Uni	384	267	4	508	459	3	318	290	3	189	173	1	—	—	—	7	3	—	—	—	—	1406	1192	11	112	104	—
Alaska	48	29	—	42	36	—	14	11	—	3	3	—	1	1	—	1	—	1	—	—	—	109	80	1	4	4	—
Alfred	69	39	—	101	79	—	49	47	—	37	35	1	—	—	—	14	10	—	—	—	—	270	210	1	34	24	—
Arizona	442	169	—	611	272	—	350	158	—	240	111	2	—	—	—	16	7	—	—	—	—	1659	717	2	59	—	1
Arkansas	219	128	1	383	329	2	207	190	1	90	83	1	—	—	—	—	—	—	—	—	—	899	730	5	38	34	—
Bradley	215	84	2	323	108	1	118	95	—	40	33	—	—	—	—	—	—	—	—	—	—	696	320	3	11	11	—
Brooklyn	354	179	—	418	295	—	445	360	—	272	225	1	—	—	—	—	—	—	2123	1324	12	3612	2383	13	163	63	1
Brown	200	75	8	275	200	1	150	140	—	104	104	—	—	—	—	—	—	—	120	120	—	849	639	9	92	78	1
Bucknell	143	79	2	167	125	1	153	132	1	81	76	1	—	—	—	—	—	—	—	—	—	544	412	5	48	10	—
Buffalo	441	321	—	529	468	—	499	229	—	126	51	—	—	—	—	6	4	—	350	—	—	1951	1073	—	—	—	—
Calif. Tech	170	—	—	185	—	—	219	—	—	211	—	—	538	—	—	—	—	—	—	—	—	1323	—	—	—	—	—
Cal. Uni	289	133	1	811	593	3	868	658	2	840	720	7	—	—	—	—	—	—	—	—	—	2808	2104	13	397	339	2
Calif. Uni. (L. A.)	173	—	3	464	—	2	291	—	—	24	—	—	—	—	—	—	—	—	—	—	—	952	—	5	6	5	—
Calif. Uni. So	234	149	—	472	402	—	666	603	2	638	404	5	—	—	—	2	3	—	—	—	—	2012	1561	7	272	213	—
Carnegie	331	144	—	368	284	—	488	434	—	467	371	1	—	—	—	1	—	—	649	396	6	2304	1629	7	309	250	—
Case	296	135	—	591	478	1	424	368	—	270	227	1	—	—	—	3	2	—	784	398	21	2368	1608	23	149	116	—
Catholic	239	—	—	464	—	—	195	—	4	77	—	—	—	—	—	—	—	—	—	—	—	975	—	4	32	—	2
Cincinnati	585	255	2	534	341	1	522	452	2	332	280	6	139	117	5	—	—	—	1780	950	186	3892	2395	202	114	87	—
Citadel	215	129	—	173	92	—	120	68	—	43	35	—	—	—	—	—	—	—	—	—	—	551	324	—	31	21	—
Clarkson	370	180	—	540	405	—	315	240	—	200	145	—	—	—	—	—	—	—	—	—	—	1425	970	—	—	—	—
Clemson	599	271	—	457	328	—	407	293	—	273	241	—	—	—	—	—	—	—	—	—	—	1736	1133	—	230	213	—
Colo. A. & M	224	123	—	225	197	—	118	109	—	63	61	1	—	—	—	—	—	—	—	—	—	630	490	1	—	—	—
Colo. Mines	282	178	1	315	268	—	307	244	1	177	153	—	—	—	—	—	—	—	—	—	—	1081	843	2	98	—	—
Colo. Uni.	562	279	8	977	810	7	624	539	12	356	331	8	6	5	—	74	63	2	513	339	—	3112	2366	37	294	254	9
Columbia	350	—	—	450	—	—	322	—	—	306	—	—	—	—	—	—	—	—	—	—	—	1428	—	—	104	—	—
Connecticut	523	314	—	624	468	—	212	192	—	84	76	—	—	—	—	—	—	—	—	—	—	1443	1050	—	45	—	—
Cooper	167	69	4	108	78	1	75	48	1	76	53	1	87	64	—	62	40	—	417	224	4	992	576	11	78	51	—
Cornell	439	130	4	777	571	7	679	564	6	495	423	4	33	27	—	—	2	—	—	—	—	2423	1717	21	364	343	7
Dayton	271	173	1	178	156	—	44	38	—	23	19	—	—	—	—	—	—	—	99	75	1	615	461	2	20	15	1
Delaware	222	105	3	227	177	1	148	127	—	79	72	—	—	—	—	—	—	—	—	—	—	676	481	4	41	38	—
Denver	330	262	—	391	361	—	170	135	3	58	47	1	—	—	—	2	—	—	—	—	—	951	805	4	21	18	—
Detroit	713	437	4	962	761	2	375	269	1	265	211	1	106	80	—	3	3	—	—	—	—	2424	1761	8	71	36	1
Drexel	391	189	—	473	342	3	405	317	3	275	245	4	170	149	2	3	1	—	—	—	—	1717	1243	12	149	117	—
Duke	151	41	2	152	126	1	148	130	—	92	82	—	—	—	—	—	—	—	—	—	—	543	379	3	148	141	2

Note: In the above table, M&V = men, veterans and non-veterans; V = veterans only; W = women.

Undergraduate Engineering Students, Enrollment as of November 1, 1947—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. (Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1946–47		
	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W
Fenn	231	150	2	278	224	5	145	118	3	54	43	—	—	—	—	—	—	—	717	488	10	1425	1023	20	56	43	—
Florida	700	—	—	500	—	—	173	153	—	151	146	—	—	—	—	—	—	—	—	—	—	1524	299	—	73	63	—
Georgia Tech	1487	753	—	1565	1242	—	770	647	—	625	538	—	18	15	—	—	—	—	—	—	—	4465	3195	—	525	457	—
Geo. Wash	340	265	2	230	203	1	72	67	1	14	13	1	—	—	—	84	79	—	375	279	2	1115	906	7	21	7	—
Harvard	—	—	—	83	40	—	59	40	—	35	24	—	—	—	—	—	—	—	—	—	—	177	104	—	75	—	—
Hawaii	166	38	—	122	48	3	31	25	—	12	9	—	—	—	—	6	1	—	—	—	—	337	121	3	3	1	—
Howard	168	124	1	148	126	—	39	31	—	31	24	—	—	—	—	—	—	—	17	14	—	403	319	1	5	1	—
Idaho	209	81	—	248	203	—	131	119	—	85	76	—	—	—	—	—	—	—	—	—	—	673	479	—	54	46	—
Ill. Tech	820	394	8	834	617	9	754	615	9	596	518	5	—	—	—	5	1	—	3797	1666	138	6806	3811	169	363	—	3
Ill. Uni	1886	907	1	2117	1759	3	1087	932	2	676	589	3	—	—	—	—	—	—	—	—	—	5766	4187	9	797	30	2
Iowa State College	808	348	—	1504	1265	3	982	889	1	481	447	1	3	3	—	15	5	—	—	—	—	3793	2957	5	450	420	3
Iowa University	41	32	—	242	198	—	221	197	—	125	110	1	—	—	—	—	—	—	—	—	—	629	537	1	90	62	2
J. Hopkins	153	63	—	227	133	—	259	161	—	135	95	—	—	—	—	—	—	—	647	307	—	1421	759	—	57	40	—
Kansas St. Coll	474	233	3	820	680	1	461	434	—	307	285	1	—	—	—	46	38	—	—	—	—	2108	1670	5	198	195	2
Kansas Uni	424	220	7	759	599	1	607	521	5	364	319	1	—	—	—	—	—	—	—	—	—	2154	1659	14	177	160	1
Kentucky	384	252	2	721	580	1	255	237	—	125	116	3	—	—	—	—	—	—	—	—	—	1485	1185	6	54	50	4
Lafayette	253	137	—	284	202	—	234	207	—	97	84	—	—	—	—	—	—	—	—	—	—	868	630	—	46	41	—
Lehigh	350	167	—	574	417	—	570	486	—	324	285	—	—	—	—	—	—	—	—	—	—	1818	1355	—	247	212	—
La. St. Uni	599	175	3	784	516	—	622	514	2	360	312	2	—	—	—	3	1	—	—	—	—	2368	1518	7	116	91	—
La. Poly	273	123	3	252	195	1	164	135	1	92	84	2	—	—	—	—	—	—	—	—	—	781	537	7	48	44	—
Louisville	169	68	—	163	128	1	110	99	—	37	30	—	63	54	—	—	—	—	—	—	—	542	379	1	117	92	—
Maine	421	246	1	662	556	2	227	202	3	216	195	1	—	—	—	13	8	—	—	—	—	1539	1207	7	90	74	—
Manhattan	299	143	—	391	267	—	283	204	—	132	109	—	—	—	—	—	—	—	—	—	—	1105	723	—	46	39	—
Marquette	346	229	—	345	248	—	292	268	—	184	150	—	—	—	—	—	—	—	—	—	—	1167	895	—	143	19	2

La. Poly	273	123	3	252	193	1	104	88	1	70	62	—	—	—	—	—	—	—	—	—	—	542	379	1	117	92	—		
Louisville	169	68	—	163	128	1	110	99	—	37	30	—	63	54	—	—	—	—	—	—	—	542	379	1	117	92	—		
Maine	421	246	1	662	556	2	227	202	3	216	195	1	—	—	—	13	8	—	—	—	—	1539	1207	7	90	74	—		
Manhattan	299	143	—	391	267	—	283	204	—	132	109	—	—	—	—	—	—	—	—	—	—	1105	723	—	46	39	—		
Marquette	346	229	—	345	248	—	292	268	—	184	150	—	—	—	—	—	—	—	—	—	—	1167	895	—	143	19	2		
Maryland	819	352	—	504	324	1	174	136	—	97	73	—	—	—	—	28	21	—	—	—	—	1622	906	1	69	55	—		
M. I. T.	713	—	2	804	—	4	994	—	4	920	—	1	3	—	—	—	—	—	—	—	—	3434	—	11	735	—	5		
Mich. M. & T.	486	273	3	819	679	11	338	298	4	196	169	—	2	1	—	—	—	—	—	—	—	1841	1420	18	151	122	2		
Mich. St. Coll.	435	—	—	872	—	—	603	—	—	339	—	—	—	—	—	—	—	—	—	—	—	2249	—	—	169	—	—.		
Mich. Uni.	631	—	8	1280	—	8	866	—	4	909	—	4	—	—	—	129	—	—	—	—	—	3815	—	24	635	—	2		
Minnesota	852	—	—	1974	—	—	1108	—	—	819	—	—	—	—	—	29	—	—	—	—	—	4782	—	—	314	—	3		
Miss. St. Coll.	257	112	—	404	334	—	283	247	1	173	162	—	—	—	—	—	—	—	—	—	—	1117	855	1	—	—	—		
Miss. Uni.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Mo. Mines	579	307	2	771	615	1	654	579	2	429	376	1	—	—	—	—	—	—	—	—	—	2433	1877	6	157	136	1		
Mo. Uni.	427	—	—	605	—	—	338	—	—	184	—	—	—	—	—	—	—	—	—	—	—	1554	—	—	117	—	—		
Mont. Mines	112	65	—	108	90	—	58	52	—	46	41	—	—	—	—	—	—	—	—	—	—	324	248	—	27	25	—		
Mont. St. Coll.	424	225	1	499	430	3	186	152	1	171	157	—	—	—	—	—	—	—	—	—	—	1280	964	5	64	59	5		
Nebraska	433	284	2	573	497	1	307	281	—	213	194	1	—	—	—	—	—	—	—	—	—	1526	1256	4	88	83	—		
Nevada	166	—	—	123	—	—	85	—	—	53	—	—	—	—	—	55	—	—	—	—	—	482	—	—	28	—	—		
Newark	424	233	—	477	383	4	340	287	—	197	160	2	—	—	—	—	—	—	838	555	11	2276	1618	17	132	67	—		
New Hampshire	253	—	1	299	194	1	227	180	1	113	95	9	—	—	—	5	—	—	—	—	—	897	469	12	46	38	—		
N. Mex. St. Coll.	168	95	1	199	162	1	89	73	1	46	39	1	—	—	—	—	—	—	—	—	—	502	369	4	25	25	—		
N. Mex. Mines	96	66	—	94	69	—	18	13	—	18	15	—	—	—	—	—	—	—	—	—	—	226	163	—	10	10	1		
N. Mex. Uni.	297	127	2	276	245	1	161	151	1	127	120	3	—	—	—	—	—	—	—	—	—	861	643	7	33	—	—		
N. Y. C. C.	1093	—	12	995	—	15	733	—	6	783	—	11	—	—	—	—	—	—	1356	—	9	4960	—	53	261	—	12		
N. Y. U.	337	212	—	392	308	—	437	330	—	433	341	—	—	—	—	49	—	—	1243	886	8	2891	2077	8	318	151	—		
N. Caro. St. Coll.	841	—	—	1114	—	—	446	—	1	515	—	1	—	—	—	—	—	—	—	—	—	2916	—	2	187	—	—		
N. Dak. A. & M.	240	—	—	256	—	—	148	—	—	57	—	—	—	—	—	—	—	—	—	—	—	701	—	—	—	—	—		
N. Dak. Uni.	113	54	—	196	167	1	93	84	—	44	43	—	—	—	—	—	—	—	—	—	—	446	348	1	19	18	—		
Northeastern	570	479	3	444	291	2	516	365	5	—	—	—	321	263	1	2	1	—	—	—	—	1853	1399	11	—	—	—		
Northwestern	166	82	1	306	214	—	268	195	3	139	115	—	126	109	—	9	4	—	6	4	—	1020	723	4	99	75	2		
Norwich	139	—	—	80	—	—	59	—	—	33	—	—	—	—	—	—	—	—	—	—	—	311	—	—	—	—	—		
Notre Dame	238	93	—	416	285	—	247	173	—	168	129	—	—	—	—	—	—	—	—	—	—	1069	680	—	164	142	—		
Ohio Uni.	330	—	—	338	—	—	110	—	—	60	—	—	—	—	—	—	—	—	—	—	—	838	—	—	—	—	—		
Ohio No. Uni.	81	56	—	130	122	—	67	60	—	15	15	—	—	—	—	—	—	—	—	—	—	293	253	—	23	18	—		
Ohio State Uni.	1148	588	7	1443	1127	10	908	781	7	557	477	7	21	20	—	22	15	—	115	29	2	4214	3037	33	273	211	2		
Okla. A. & M.	601	316	2	970	811	6	576	517	3	336	306	5	—	—	—	5	1	1	—	—	—	2488	1951	17	127	—	1		
Okla. Uni.	1200	675	7	1104	919	5	591	543	5	467	422	8	—	—	—	—	—	—	—	—	—	3362	2559	25	286	246	2		
Oregon	387	179	—	641	551	1	428	391	2	264	241	3	—	—	—	—	—	—	—	—	—	1720	1362	6	177	158	—		
Pennsylvania	220	97	—	244	170	—	241	200	—	118	101	—	—	—	—	—	—	—	—	—	—	823	568	—	41	26	—		
Pa. State Coll.	1047	—	—	1299	—	2	805	—	6	617	—	1	—	—	—	13	—	—	—	—	—	3781	—	9	263	—	—		
Pittsburgh	864	627	2	734	600	—	629	559	1	349	312	3	—	—	—	7	4	—	490	310	2	3073	2412	8	275	250	—		
Puerto Rico	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		

Note: In the above table, M&V = men, veterans and non-veterans; V = veterans only; W = women.

Undergraduate Engineering Students, Enrollment as of November 1, 1947—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1946–47		
	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W
Pratt	221	134	—	285	222	1	136	110	2	114	90	1	—	—	—	—	—	—	—	—	—	756	556	4	31	6	2
Princeton	160	23	—	183	111	—	168	118	—	107	95	—	—	—	—	—	—	—	—	—	—	618	347	—	124	118	—
Purdue	1976	862	19	2367	1824	12	1964	1679	16	1649	1454	10	—	—	—	4	3	1	—	—	—	7960	5822	58	870	—	9
Rensselaer	997	608	4	1273	1025	7	796	629	7	563	480	5	—	—	—	22	14	—	140	92	17	3791	2848	40	497	445	4
R. I. St. Coll.	173	89	2	273	195	2	176	113	4	108	55	2	—	—	—	—	—	—	—	—	—	730	452	10	—	—	—
Rice	156	20	—	153	87	1	137	114	—	152	135	—	—	—	—	—	—	—	—	—	—	598	356	1	118	—	—
Rochester	115	—	—	133	—	—	105	—	—	50	—	—	13	—	—	—	—	—	—	—	—	416	—	—	76	—	—
Rose	112	67	—	173	133	—	215	203	—	75	65	—	—	—	—	—	—	—	—	—	—	575	468	—	79	67	—
Rutgers	305	155	1	230	158	1	236	212	1	117	102	1	—	—	—	—	—	—	—	—	—	888	627	4	42	42	—
Santa Clara	90	22	—	93	50	—	63	47	—	45	40	—	—	—	—	—	—	—	—	—	—	291	159	—	18	4	—
S. Caro. Uni.	213	73	—	266	241	—	170	162	—	115	111	1	—	—	—	—	—	—	—	—	—	764	587	1	—	—	—
S. Dak. Mines	184	95	—	225	180	—	127	121	—	67	58	1	—	—	—	—	—	—	—	—	—	603	454	1	49	46	—
S. Dak. St. Coll.	196	62	—	186	97	—	91	58	1	47	42	1	—	—	—	—	—	—	—	—	—	520	259	2	26	24	—
So. Meth. Uni.	278	201	—	269	243	—	214	199	1	61	56	2	—	—	—	4	2	—	—	—	—	826	701	3	44	39	1
S. W. La.	282	131	—	225	186	1	83	65	—	41	36	—	—	—	—	—	—	—	—	—	—	631	418	1	18	13	1
Stanford	530	—	—	—	—	—	—	—	—	365	—	—	—	—	—	—	—	—	—	—	—	895	—	—	—	—	—
Stevens	497	312	—	576	490	—	276	193	—	132	116	—	—	—	—	—	—	—	—	—	—	1481	1111	—	108	—	—
Swarthmore	28	10	—	66	34	—	40	31	1	30	25	—	—	—	—	1	1	—	—	—	—	165	101	1	20	17	—
Syracuse	417	219	6	729	493	8	393	310	2	158	113	2	—	—	—	3	1	—	—	—	—	1700	1136	18	64	63	2
Tennessee	398	211	1	757	634	2	361	323	1	141	123	—	—	—	—	5	2	—	—	—	—	1662	1293	4	82	—	—
Texas A. & I.	168	84	2	137	93	2	63	51	—	56	47	—	—	—	—	—	—	—	—	—	—	424	275	4	9	—	—
Texas A. & M.	1197	476	—	1155	867	—	1017	802	—	779	687	—	48	34	—	5	3	—	—	—	—	4201	2869	—	587	521	—
Texas Tech.	468	—	2	554	—	4	404	—	2	248	—	3	—	—	—	—	—	—	—	—	—	1674	—	11	119	—	1
Texas Uni.	667	543	7	1214	983	8	1134	920	6	659	530	5	9	7	1	—	—	—	—	—	—	3683	2983	27	398	348	6
Thayer	90	41	—	75	55	—	52	38	—	55	53	—	57	56	—	—	—	—	—	—	—	329	243	—	73	69	—
Toledo	246	108	3	309	237	2	221	207	1	137	112	—	—	—	—	—	—	—	—	—	—	913	664	6	—	—	—
Tufts	213	100	—	168	102	2	139	121	1	140	131	—	—	—	—	—	—	—	—	—	—	660	454	3	160	145	1
Tulane	172	58	—	199	129	—	158	132	—	109	88	—	—	—	—	—	—	—	—	—	—	638	407	—	88	75	1
Tulsa	197	132	1	243	210	1	124	108	—	63	47	1	—	—	—	8	5	1	—	—	—	635	502	4	21	16	—

Toledo	246	108	3	309	237	2	221	207	1	137	112	—	—	—	—	—	—	—	—	—	—	913	664	6	—	—	—
Tufts	213	100	—	168	102	2	139	121	1	140	131	—	—	—	—	—	—	—	—	—	—	660	454	3	160	145	1
Tulane	172	58	—	199	129	—	158	132	—	109	88	—	—	—	—	—	—	—	—	—	—	638	407	—	88	75	1
Tulsa	197	132	1	243	210	1	124	108	—	63	47	1	—	—	—	8	5	1	—	—	—	635	502	4	21	16	—

U. S. Coast Guard	129	24	—	93	38	—	62	26	—	56	46	—	—	—	—	—	—	—	—	—	—	340	134	—	—	—	—
Union	137	60	—	156	118	—	77	59	—	32	21	—	—	—	—	—	—	—	77	37	9	479	295	9	16	13	—
Utah Agri. Coll.	82	—	—	101	—	—	50	—	—	29	—	—	—	—	—	—	—	—	—	—	—	262	—	—	17	17	—
Utah Uni.	356	109	—	417	315	1	322	243	—	215	178	—	—	—	—	—	—	—	—	—	—	1310	845	1	89	68	—
Vanderbilt	156	44	—	257	217	—	250	221	2	71	62	—	—	—	—	—	—	—	—	—	—	734	544	2	50	47	—
Vermont	149	80	—	182	164	1	109	100	1	34	27	2	—	—	—	—	—	—	—	—	—	474	371	4	11	11	1
Villanova	195	120	—	358	215	—	187	120	—	55	40	—	—	—	—	—	—	—	—	—	—	795	495	—	—	—	—
Va. Mil.	157	36	—	155	54	—	108	60	—	50	46	—	—	—	—	—	—	—	—	—	—	470	196	—	98	72	—
Va. Poly	910	487	4	1185	896	—	690	570	4	407	361	3	—	—	—	2	2	—	—	—	—	3194	2316	11	358	328	3
Va. Uni.	142	69	—	178	154	—	164	143	—	75	66	—	—	—	—	—	—	1	—	—	—	559	432	1	61	58	—
Wash. St. Coll.	—	—	—	345	276	1	217	156	1	178	127	3	—	—	—	—	—	—	—	—	—	740	559	5	—	—	—
Wash. Uni.	615	338	6	503	437	—	413	352	3	406	355	1	11	8	—	12	—	—	—	—	—	1960	1490	10	208	172	1
Wash. Uni. (St. L.)	264	115	—	369	264	5	359	307	1	239	195	—	—	—	—	1	1	—	—	—	—	1232	882	6	93	65	1
Wayne	309	—	4	465	—	5	299	—	6	160	—	1	—	—	—	5	—	—	—	—	—	1238	—	16	—	—	—
Webb Inst.	22	5	—	25	10	—	10	3	—	5	4	—	—	—	—	—	—	—	—	—	—	62	22	—	—	—	—
W. Va. Uni.	330	183	2	596	451	3	265	209	1	169	130	1	—	—	—	—	—	—	—	—	—	1360	973	7	74	—	2
Wisconsin	506	290	—	1096	913	—	833	705	4	528	455	1	—	—	—	—	—	—	—	—	—	2963	2363	5	254	—	1
Worcester	212	96	—	207	129	—	258	227	—	167	129	—	—	—	—	—	—	—	—	—	—	844	581	—	123	108	—
Wyoming	240	124	1	268	222	5	142	123	1	92	82	—	—	—	—	—	—	—	—	—	—	742	551	7	53	52	2
Yale	240	—	—	452	259	—	407	314	—	320	289	—	—	—	—	3	1	—	—	—	—	1422	863	—	316	—	—

Canadian Schools

Alberta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ecole	148	16	—	105	14	—	61	3	—	76	3	—	70	1	—	—	—	—	—	—	—	460	37	—	57	—	—
McGill	421	292	5	609	491	2	382	248	2	220	113	3	9	3	3	—	—	—	—	—	—	1641	1147	15	195	56	5
New Brunswick	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Queens	334	166	1	299	241	—	245	203	—	224	131	1	—	—	—	—	—	—	—	—	—	1102	741	2	146	49	—
Toronto	1209	852	3	1447	1103	4	1324	1086	3	513	290	4	9	2	—	—	—	—	—	—	—	4502	3333	14	272	—	5
Canadian Sch.	2112	1326	9	2460	1849	6	2012	1540	5	1033	537	8	88	6	3	—	—	—	—	—	—	7705	5258	31	670	105	10
U. S. Schools	55377	23158	205	70644	44517	223	47979	32940	201	32186	21604	177	1837	1072	9	812	360	7	16653	8493	438	225488	132144	1260	18464	9783	128
Enrollment in Extension Centers*	1924	634	1	748	418	—	47	38	—	6	2	—	—	—	—	31	16	—	675	420	—	3431	1528	1	—	—	—
Grand Total (149 Inst.)	59413	25118	215	73852	46784	229	50038	34518	206	33225	22143	185	1925	1078	12	843	376	7	17328	8913	438	236624	138930	1292	19134	9888	138

* Extension center enrollment figures are given in the supplementary table for those schools which reported their extension enrollment separately.

Note: In the above table, M&V = men, veterans and non-veterans; V = veterans only; W = women.

Supplementary Table

Undergraduate Engineering Students, Enrollment in Extension Centers as of November 1, 1947

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. (Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1946–47		
	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W
Aeronautical	74	11	—	3	2	—	2	1	—	—	—	—	—	—	—	3	1	—	—	—	—	82	15	—	—	—	—
Agricultural	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Architectural	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ceramic	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chemical	203	84	—	66	53	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	270	138	—	—	—	—
Civil	314	135	1	88	69	—	5	3	—	2	—	—	—	—	—	6	4	—	—	—	—	415	211	1	—	—	—
Electrical	450	157	—	175	143	—	9	8	—	—	—	—	—	—	—	4	1	—	—	—	—	638	309	—	—	—	—
Eng. Physics	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
General	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Industrial	34	27	—	10	6	—	2	1	—	—	—	—	—	—	—	3	1	—	—	—	—	49	35	—	—	—	—
Mechanical	565	201	—	161	131	—	28	24	—	4	2	—	—	—	—	15	9	—	—	—	—	773	367	—	—	—	—
Metallurgical	43	11	—	13	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	56	21	—	—	—	—
Mining	13	8	—	5	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18	12	—	—	—	—
Naval Arch. & Marine	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Petroleum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unclassified	228	—	—	227	—	—	—	—	—	—	—	—	—	—	—	—	—	—	675	420	—	1230	420	—	—	—	—
Totals	1924	634	1	748	418	—	47	38	—	6	2	—	—	—	—	31	16	—	675	420	—	3431	1528	1	—	—	—
Alabama Uni.	325	239	1	126	91	—	20	11	—	6	2	—	—	—	—	31	16	—	—	—	—	508	359	1	—	—	—
Georgia Tech	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	675	420	—	675	420	—	—	—	—
Okla. A. & M.	223	—	—	227	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	450	—	—	—	—	—
Purdue Uni.	659	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	659	—	—	—	—	—
Uni. of Wis.	717	395	—	395	327	—	27	27	—	—	—	—	—	—	—	—	—	—	—	—	—	1139	749	—	—	—	—
Totals	1924	634	1	748	418	—	47	38	—	6	2	—	—	—	—	31	16	—	675	420	—	3431	1528	1	—	—	—

Uni. of Wis.	717	395	—	395	327	—	27	27	—	—	—	—	—	—	—	—	—	—	—	—	—	1139	749	—	—	—	—
Totals	1924	634	1	748	418	—	47	38	—	6	2	—	—	—	—	31	16	—	675	420	—	3431	1528	1	—	—	—

Graduate Engineering Students, Enrollment as of November 1, 1947

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree												
	Full Time Resident Students			Part Time Resident Students			Evening Students			Totals			Masters Degrees Conferred in 1946–47			Full Time Resident Students			Part Time Resident Students			Evening Students			Totals			Doctors Degrees Conferred in 1946–47		
	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W
Aeronautical	341	131	1	126	53	—	67	31	—	534	215	1	192	23	—	27	2	1	29	4	—	11	3	—	67	9	1	2	—	—
Agricultural	66	21	—	31	12	—	—	—	—	97	33	—	23	12	—	5	—	—	5	4	—	—	—	—	10	4	—	—	—	—
Architectural	29	22	1	9	2	—	—	—	—	38	24	1	11	5	—	1	—	—	1	1	—	—	—	—	2	1	—	—	—	—
Ceramic	40	10	1	22	11	—	—	—	—	62	21	1	29	12	1	16	3	—	7	—	—	—	—	—	23	3	—	2	—	—
Chemical	1084	426	2	756	319	23	487	222	24	2327	967	49	654	196	2	304	111	3	327	106	8	26	5	—	657	222	11	55	5	—
Civil	955	386	7	473	232	1	265	161	—	1693	779	8	668	260	—	71	14	—	43	18	—	9	3	—	123	35	—	15	3	—
Electrical	1417	494	6	945	424	4	792	281	—	3154	1199	10	555	156	—	127	24	3	177	43	—	7	2	—	311	69	3	26	1	—
Eng. Physics	70	52	3	141	70	1	62	23	2	273	145	6	87	39	5	19	11	—	87	30	4	—	—	—	106	41	4	7	—	—
Industrial	147	64	—	164	29	—	244	134	1	555	227	1	119	7	—	2	—	—	3	2	—	15	3	—	20	5	—	—	—	—
Mechanical	858	360	1	792	379	—	556	250	3	2206	989	4	512	89	—	61	19	—	38	9	—	10	5	—	109	33	—	9	1	—
Metallurgical	209	74	—	121	42	2	209	61	—	539	177	2	137	53	—	36	14	—	37	3	—	1	1	—	74	18	—	10	1	—
Mining	27	9	1	20	3	—	—	—	—	47	12	1	43	5	—	5	—	—	2	—	—	—	—	—	7	—	—	2	1	—
Naval Arch. & Marine	84	—	—	—	—	—	—	—	—	84	—	—	47	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Petroleum	81	58	—	6	—	—	2	2	—	89	60	—	41	10	—	4	1	—	2	—	—	—	—	—	6	1	—	3	—	—
Unclassified	78	37	7	83	56	1	792	348	14	953	441	22	23	7	—	27	—	—	16	9	—	—	—	—	43	9	—	2	—	—
Totals	5486	2144	30	3689	1632	32	3476	1513	44	12651	5289	106	3141	874	8	705	199	7	774	229	12	79	22	—	1558	450	19	133	12	—

Note: In the above table, M&V = men, veterans and non-veterans; V = veterans only; W = women.

Graduate Engineering Students, Enrollment as of November 1, 1947—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree												
	Full Time Resident Students			Part Time Resident Students			Evening Students			Totals			Masters Degrees Conferred in 1946–47			Full Time Resident Students			Part Time Resident Students			Evening Students			Totals			Doctors Degrees Conferred in 1946–47		
	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W
Ala. Poly	—	—	—	1	1	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ala. Uni	18	12	—	—	—	—	—	—	—	18	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alfred	7	—	—	2	2	—	—	—	—	9	2	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arizona	3	2	—	2	1	—	—	—	—	5	3	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bradley	—	—	—	1	1	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Brooklyn	141	60	3	953	486	23	197	74	20	1291	620	46	154	18	2	70	28	4	247	53	9	—	—	—	317	81	13	—	1	—
Brown	—	—	—	18	18	—	—	—	—	18	18	—	—	—	—	—	—	—	1	1	—	—	—	—	1	1	—	—	—	—
Buffalo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bucknell	—	—	—	11	6	1	—	—	—	11	6	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calif. Tech	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calif. Uni	163	89	—	—	—	—	—	—	—	163	89	—	38	10	—	31	10	—	—	—	—	—	—	—	31	10	—	—	1	—
Calif. U. (L. A.)	8	6	—	33	19	1	28	19	—	69	44	1	—	—	—	—	—	—	11	8	—	—	—	—	11	8	—	—	—	—
Calif. Uni. So	72	59	—	24	13	—	4	3	—	100	75	—	17	10	—	1	1	—	—	—	—	—	—	—	1	1	—	—	—	—
Carnegie	60	32	1	13	8	—	113	53	—	186	93	1	68	36	—	38	14	—	10	2	—	—	—	—	48	16	—	3	—	—
Case	21	17	—	18	10	—	94	43	—	133	70	—	41	20	—	4	—	—	—	—	—	3	1	—	7	1	—	—	—	—
Catholic	3	—	—	21	—	—	—	—	—	24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cincinnati	6	6	—	3	3	—	—	—	—	9	9	—	—	—	—	1	1	—	11	5	—	—	—	—	12	6	—	2	2	—
Clemson	—	—	—	3	3	—	—	—	—	3	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Colo. A. & M	8	5	—	14	8	—	—	—	—	22	13	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Colo. Mines	42	21	—	—	—	—	—	—	—	42	21	—	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Colo. Uni	54	37	—	50	40	—	182	113	—	286	190	—	33	21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Columbia	—	—	—	376	—	—	—	—	—	376	—	—	126	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cornell	57	46	—	38	33	—	—	—	—	95	79	—	36	28	—	15	7	—	5	5	—	—	—	—	20	12	—	3	1	—
Delaware	19	14	—	5	3	—	61	12	—	85	29	—	6	1	—	14	6	—	3	—	—	2	—	—	19	6	—	—	—	—
Denver	6	4	—	1	1	—	5	4	—	12	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Florida	1	1	—	31	24	—	—	—	—	32	25	—	6	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Delaware	19	14	—	5	3	—	61	12	—	85	29	—	6	1	—	14	6	—	3	—	—	2	—	—	19	6	—	—	—	—
Denver	6	4	—	1	1	—	5	4	—	12	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Florida	1	1	—	31	24	—	—	—	—	32	25	—	6	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Geo. Tech	120	80	—	—	—	—	—	—	—	120	80	—	29	21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Harvard	288	171	—	22	11	3	—	—	—	310	182	3	243	132	—	35	13	—	45	18	—	—	—	—	80	31	—	9	—	—
Idaho	13	8	—	5	—	—	—	—	—	18	8	—	7	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ill. Tech	124	84	5	—	—	—	526	225	5	650	309	10	38	—	—	46	—	—	—	—	—	—	—	—	46	—	—	6	—	—
Ill. Uni	266	122	3	168	103	1	—	—	—	429	225	4	203	118	5	42	9	—	91	41	3	—	—	—	133	50	3	6	—	—
Iowa St. Coll	70	26	—	68	48	—	—	—	—	138	74	—	50	23	—	10	2	—	22	11	—	—	—	—	32	13	—	3	—	—
Iowa Uni	56	18	—	24	12	—	—	—	—	80	30	—	50	17	—	14	7	—	10	4	—	—	—	—	24	11	—	1	—	—
J. Hopkins	104	79	—	25	10	—	49	23	—	178	112	—	26	15	—	29	12	—	20	13	—	2	—	—	51	25	—	5	3	—
Kans. St. Coll	4	4	—	41	32	—	—	—	—	45	36	—	15	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kansas Univ	—	—	—	52	—	—	—	—	—	52	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kentucky	8	5	—	9	9	—	—	—	—	17	14	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lafayette	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lehigh	36	27	—	47	19	1	—	—	—	83	46	1	31	19	—	3	3	—	16	7	—	—	—	—	19	10	—	1	—	—
La. St. Uni	45	31	—	53	20	—	—	—	—	98	51	—	7	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Louisville	18	11	—	—	—	—	7	1	—	25	12	—	16	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Maine	11	9	—	7	4	—	—	—	—	18	13	—	8	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Maryland	—	—	—	263	178	—	—	—	—	263	178	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
M. I. T	925	—	9	—	—	—	—	—	—	925	—	9	384	—	—	—	—	—	—	—	—	—	—	—	—	—	—	39	—	—
Mich. M. & T	20	14	—	—	—	—	—	—	—	20	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mich. St. Coll	43	—	—	34	—	—	—	—	—	77	—	—	11	—	—	3	—	—	7	—	—	—	—	—	10	—	—	2	—	—
Mich. Uni	471	—	2	58	—	—	—	—	—	529	—	2	206	—	—	84	—	2	20	—	—	—	—	—	104	—	2	9	—	—
Minnesota	113	33	—	71	27	1	—	—	—	184	60	1	67	—	—	17	10	—	41	11	—	—	—	—	58	21	—	3	—	—
Mo. Mines	76	54	2	—	—	—	—	—	—	76	54	2	19	13	—	8	2	—	—	—	—	—	—	—	8	2	—	—	—	—
Mo. Uni	8	—	—	16	—	—	—	—	—	24	—	—	21	—	—	—	—	—	2	—	—	—	—	—	2	—	—	—	—	—
Mont. Mines	11	7	—	—	—	—	—	—	—	11	7	—	5	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mont. St. Coll	31	16	1	—	—	—	—	—	—	31	16	1	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nebraska	5	2	—	20	9	—	—	—	—	25	11	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Newark	—	—	—	—	—	—	239	120	6	239	120	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
New Hampshire	6	4	—	4	4	—	—	—	—	10	8	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
New Mex. S. of Mines	—	—	—	23	18	—	—	—	—	23	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
New Mex. Uni	—	—	—	1	1	—	—	—	—	1	1	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N. Y. C. C	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: In the above table, M&V = men, veterans and non-veterans; V = veterans only; W = women.

Graduate Engineering Students, Enrollment as of November 1, 1947—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree												
	Full Time Resident Students			Part Time Resident Students			Evening Students			Totals			Masters Degrees Conferred in 1946–47			Full Time Resident Students			Part Time Resident Students			Evening Students			Totals			Doctors Degrees Conferred in 1946–47		
	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W	M&V	V	W
New York Uni.	100	41	1	—	—	—	529	298	2	629	339	3	77	15	—	12	5	—	—	—	—	71	21	—	83	26	—	—	—	—
N. Caro. St. Coll.	26	22	—	46	17	—	—	—	—	172	39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Northwestern	27	11	—	46	33	—	10	2	—	83	46	—	41	23	—	11	2	—	15	11	—	—	—	—	26	13	—	—	—	—
Notre Dame	56	38	—	—	—	—	—	—	—	56	38	—	21	18	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—
N. Dak. Uni.	3	3	—	—	—	—	—	—	—	3	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ohio St. Uni.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Okla. A. & M.	65	44	—	139	65	—	778	420	8	65	44	—	27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Okla. Uni.	42	37	—	5	—	—	—	—	—	47	37	—	6	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oregon	49	32	—	1	1	—	—	—	—	50	33	—	16	10	—	5	1	—	—	—	—	—	—	—	5	1	—	—	—	—
Pennsylvania	61	18	—	54	16	—	277	110	—	392	144	—	25	1	—	18	8	—	25	2	—	—	—	—	43	10	—	3	—	—
Pa. St. Coll.	47	—	—	113	—	1	—	—	—	160	—	—	53	—	—	21	—	—	41	—	—	—	—	—	62	—	—	6	—	—
Pittsburgh	25	—	—	31	—	—	381	—	—	437	—	—	43	—	—	—	—	—	49	—	—	—	—	—	49	—	—	5	—	—
Princeton	40	32	—	33	24	—	—	—	—	73	56	—	28	23	—	5	5	—	14	10	—	—	—	—	19	15	—	—	—	—
Purdue	100	47	1	186	115	—	—	—	—	286	162	1	114	—	—	12	5	1	34	15	—	—	—	—	46	20	1	2	—	—
Rensselaer	76	45	—	134	99	—	27	19	—	237	163	—	68	46	—	5	3	—	10	2	—	—	—	—	15	5	—	—	—	—
R. I. St. Coll.	4	4	—	4	3	—	—	—	—	8	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rice	10	—	—	—	—	—	—	—	—	10	—	—	5	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rochester	10	10	—	14	7	—	—	—	—	24	17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rutgers	2	—	—	20	13	—	—	—	—	22	13	—	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S. Caro. Uni.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S. Dak. Mines	2	—	1	—	—	—	—	—	—	2	—	1	3	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S. Dak. St. Coll.	—	—	—	3	—	—	—	—	—	3	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stanford	244	—	—	—	—	—	—	—	—	244	—	—	163	—	—	64	—	—	—	—	—	—	—	—	64	—	—	3	—	—
Stevens	6	5	—	14	—	—	557	321	6	577	326	6	54	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Syracuse	21	7	—	17	3	—	52	3	—	90	13	—	7	5	—	1	1	—	—	—	—	1	—	—	2	1	—	—	—	—

S. Dak. St. Coll.	—	—	—	3	—	—	—	—	—	3	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stanford	244	—	—	—	—	—	—	—	—	244	—	—	163	—	—	64	—	—	—	—	—	—	—	—	64	—	—	3	—	—
Stevens	6	5	—	14	—	—	557	321	6	577	326	6	54	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Syracuse	21	7	—	17	3	—	52	3	—	90	13	—	7	5	—	1	1	—	—	—	—	1	—	—	2	1	—	—	—	—
Tennessee	162	52	—	—	—	—	—	—	—	162	52	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Texas A. & M.	72	39	—	39	13	—	—	—	—	111	52	—	23	23	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Texas Uni.	133	103	1	44	31	—	—	—	—	177	134	1	50	—	—	17	10	—	10	4	—	—	—	—	27	14	—	2	—	—
Thayer	57	56	—	—	—	—	—	—	—	57	56	—	28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tulane	2	2	—	16	16	—	—	—	—	18	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tulsa	19	16	—	—	—	—	—	—	—	19	16	—	11	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Texas Tech	—	—	—	2	1	—	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Union	—	—	—	—	—	—	128	65	5	128	65	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Utah Uni.	25	13	—	—	—	—	—	—	—	25	13	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Utah Agri.	8	8	—	4	2	—	—	—	—	12	10	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vanderbilt	4	2	—	3	1	—	—	—	—	7	3	—	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vermont	3	2	—	—	—	—	—	—	—	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Va. Poly	91	75	—	—	—	—	—	—	—	91	75	—	37	34	—	3	2	—	2	2	—	—	—	—	5	4	—	—	—	—
Wash. St. Coll.	11	6	—	7	—	—	—	—	—	18	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wash. Uni.	92	52	—	—	—	—	—	—	—	92	52	—	25	10	—	10	7	—	—	—	—	—	—	—	10	7	—	—	—	—
Wash. U. (St. L.)	28	9	—	31	25	—	—	—	—	59	34	—	14	7	—	8	3	—	1	—	—	—	—	—	9	3	—	—	—	—
Wayne	4	—	—	24	—	—	5	4	—	33	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
W. Va. Uni.	6	6	—	14	14	—	—	—	—	20	20	—	4	4	—	—	—	—	4	4	—	—	—	—	4	4	—	1	1	—
Wisconsin	33	—	—	91	—	—	—	—	—	124	—	—	44	—	—	—	—	—	4	—	—	—	—	—	4	—	—	7	—	—
Worcester	28	24	—	10	8	—	—	—	—	38	32	—	17	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wyoming	14	13	—	1	—	—	—	—	—	15	13	—	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Yale	66	52	—	—	—	—	—	—	—	66	52	—	62	46	—	40	22	—	—	—	—	—	—	—	40	22	—	5	3	—

Canadian Schools

Alberta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ecole	3	—	—	—	—	—	—	—	—	3	—	—	3	—	—	—	—	—	1	—	—	—	—	—	1	—	—	1	—	—
McGill	9	1	—	12	5	—	5	1	—	26	7	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Queens	6	1	—	—	—	—	—	—	—	6	1	—	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Toronto	33	—	—	46	—	—	—	—	—	79	—	—	47	—	—	8	—	—	1	—	—	—	—	—	9	—	—	5	—	—
Canadian Schools	51	2	—	58	5	—	5	1	—	114	8	—	59	3	—	8	—	—	2	—	—	—	—	—	10	—	—	6	—	—
U. S. Schools	5435	2142	30	3631	1627	32	3471	1512	44	12537	5281	106	3082	871	8	697	199	7	772	229	12	79	22	—	1548	450	19	127	12	—
Grand Total (104 Inst.)	5486	2144	30	3689	1632	32	3476	1513	44	12651	5289	106	3141	874	8	705	199	7	774	229	12	79	22	—	1558	450	19	133	12	—

Note: In the above table, M&V = men, veterans and non-veterans; V = veterans only; W = women.

PRE-WAR AND POST-WAR COMPARISON OF ENGINEERING COLLEGE ENROLLMENT

(for United States only)

Undergraduate Enrollment

Year	Freshman	Sophomore	Junior	Senior	5th Yr.	Special	Evening	Total	No. of First Degrees
1940–41	33,175	24,242	20,120	16,310	985	514	12,945	108,291	11,358 (1939–40)
1947–48	57,507	71,615	48,227	32,369	1,846	850	17,766	230,180	18,592 (1946–47)
% Increase 1947–48 over 1940–41	73.5%	195%	140%	98%	87%	65%	37%	113%	63.5%

Graduate Enrollment

	Master's Degrees					Doctor's Degrees				
Year	Full Time	Part Time	Evening	Total	Master's Degrees	Full Time	Part Time	Evening	Total	Doctor's Degrees
1940–41	2003	980	1599	4582	1318 (1939–40)	404	179	41	624	108 (1939–40)
1947–48	5465	3663	3515	12643	3090 (1946–47)	704	784	79	1567	127 (1946–47)
% Increase 1947–48 over 1940–41	173%	274%	120%	176%	134%	74%	337%	93%	151%	17.8%

	1940–41	1947–48
Total college enrollment in U. S.	1,490,000	2,333,000
Engineering enrollment in U. S.	113,497	244,390
Percent engineering to total	7.6%	10.5%

Engineering enrollment in U. S.	118,191	211,870
Percent engineering to total	7.6%	10.5%